DOCUMENT RESUME

ED 224 820 TM 830 002

AUTHOR Commons, C., Ed.; Martin, P., Ed.
TITLE Australian Chemistry Test Item Bank: Years 11 and 12. Volume 2.
INSTITUTION Australian Council for Educational Research, Hawthorn.
REPORT NO ISBN-0-85563-975-x; ISBN-0-85563-977-6
PUB DATE Jun 82
NOTE 195p.; For related documents, see ED 189 193, ED 206 719, and TM 830 001.
AVAILABLE FROM Australian Council for Educational Research Limited, Radford House, Frederick Street, Hawthorn, Victoria, Australia 3122
PUB TYPE Tests/Evaluation Instruments (160)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Chemistry; Foreign Countries; Grade 11; Grade 12; High Schools; *Item Banks; Multiple Choice Tests; Science Instruction; *Science Tests; *Secondary School Science; *Test Items
IDENTIFIERS Australia

ABSTRACT

The second volume of the Australian Chemistry Test Item Bank, consisting of two volumes, contains nearly 2000 multiple-choice items related to the chemistry taught in Year 11 and Year 12 courses in Australia. Items which were written during 1979 and 1980 were initially published in the "ACER Chemistry Test Item Collection" and in the "ACER Chemistry Test Item Collection Supplement" in order to provide Victorian teachers with an immediate source of items for the "core" and "options" section of their new Year 12 course, pending publication of the item bank. The current publication contains most of the 542 items in these collections, together with hundreds of items which have not been released previously. The items are designed to assist teachers in the preparation of tests for diagnostic and achievement purposes. The introduction includes instructions on using the item bank and a content classification of the items in volumes 1 and 2. The appendix includes the item bank for (1) redox reactions, (2) electrochemical cells, (3) electrolysis, (4) measurement and chemical techniques, (5) carbon chemistry, (6) silicon chemistry, (7) nitrogen chemistry, (8) phosphorus chemistry, (9) oxygen chemistry, (10) sulfur chemistry, (11) halogen chemistry, and (12) metals. (Author/PN)

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Published by: The Australian Council for Educational Research Limited
Radford House, Frederick Street, Hawthorn, Victoria 3122
June 1982

Typeset by: Meredith Trade Lino Pty Ltd
308 Swan Street, Burnley, Victoria 3121
Printed and bound by: Allanby Press Printers Pty Limited
1a Crescent Road, Camberwell, Victoria 3124

AUSTRALIAN CHEMISTRY TEST ITEM BANK

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ISBN O 85563 975 x Australian Test Item Bank — Volumes 1 & 2
ISBN O 85563 977 6 Volume 2

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CONTENTS

Acknowledgements iv
Introduction vi
The Australian Chemistry Test Item Bank Project vii
Using the Item Bank viii
- Uses for the items
- Preparation of tests
- Selecting an item
- Writing additional test items
- Symbols and chemical nomenclature

Content Axis Volumes 1 & 2 1
Appendix 10

O Redox Reactions 11
P Electrochemical Cells 23
Q Electrolysis 31
R Measurement and Chemical Techniques 41
S Carbon Chemistry 59
T Silicon Chemistry 111
U Nitrogen Chemistry 119
V Phosphorus Chemistry 145
W Oxygen Chemistry 149
X Sulfur Chemistry 151
Y Halogen Chemistry 159
Z Metals 163

ACKNOWLEDGEMENTS

Many teachers have been involved in the writing, editing and trial testing of the items in this publication. The ACER is grateful for the enthusiastic support that teachers have given to the project.

The following people have contributed to the item bank, or have assisted with editing of items:

Mr O. Andrews	Croydon High School
Mr S. Bayley	Princes Hill High School
Ms A. Becker	Fintona Girls School, Balwyn
Mr R. Beven	Findon High School
Mr R. Bland	Norwood High School
Mr K. Buckley	Melbourne High School
Mr N. Burford	Henley High School
Mr R. Charlesworth	Albert Park High School
Mr E. Clarke	Syndal High School
Mr J. Coggins	Salisbury East High School
Dr C. Commons	Camberwell High School
Mrs P. Commons	Melbourne High School
Mr D. Couper	Australian Council for Educational Research
Mr K. Creed	Board of Inspectors of Secondary Schools, Victoria
Mr M. Cropley	Victorian Institute of Secondary Education
Mr W. Facey	Rosebud High School
Mr S. Farish	Australian Council for Educational Research
Miss J. Forster	Blackburn High School
Mr R. Fox	Carey Baptist Grammar School
Mr J. Gilson	Haileybury College, Keysborough
Mr W. Goldstraw	Yarra Valley Church of England School
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Mr D. Hennell	Melbourne High School
Mr D. Hyatt	Mitcham High School
Mr C. James	Camberwell High School
Mr D. Jenkins	Orbost High School
Mr J. Jenkins	Camberwell Grammar School
Mr B. Jones	Melbourne Church of England Grammar School
Mr B. Kelly	Swan Hill High School
Mr P. Kendall	St Joseph's Regional College, Echuca
Mr J. Kent	Presbyterian Ladies College
Dr P. Lewis	Scotch College, Hawthorn
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Mr P. Martin	Elwood High School
Ms A. Meehan	Upfield High School
Mr T. Mewett	Mt Gambier High School
Mr D. Moody	Doncaster East High School
Ms K. Mullins-Gunst	Academy of Mary Immaculate, Fitzroy
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Mr C. Oates	Karingal High School
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Mr I. Sullivan	Camberwell Girls Grammar School
Mr R. Todd	Findon High School
Ms T. Vandertouw	Education Research and Development Committee Fellow
Ms M. Vandertouw	MacRobertson Girls High School
Mrs R. Warboys	Presbyterian Ladies College, Burwood
Mr B. White	Derrinallum High School
Mr D. Williams	Princes Hill High School
Mr J. Williams	Flemington High School

The development of items related to chemistry taught in South Australia was assisted by Mr P. Schodde, Curriculum Directorate, Education Department of South Australia.

In order to provide as complete a coverage of each topic area as possible, a number of items have been reprinted from exam papers produced by the Victorian Universities and Schools Examinations Board, Victorian Institute of Secondary Education, Public Examinations Board of South Australia and from the *Bank of Items for HSC Chemistry* published by the Education Department of Tasmania.

Each of these organizations is thanked for permission to incorporate items in this publication. Items from ACER's *Science Item Bank* and the *Series L* and *Series M Chemistry Diagnostic Tests* have also been included. A list of items from these sources is given in the Appendix.

Finally, the publishers wish to thank the Education Department of Victoria for the secondment of staff to this project from 1979 to 1981 and the teachers and students in over 200 Australian secondary schools who assisted in the trial testing of items.

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INTRODUCTION

The Australian Chemistry Test Item Bank consists of two volumes containing nearly 2000 multiple-choice items related to the chemistry taught in Year 11 and Year 12 courses in Australia. Most of the items have been written by practising teachers and all items have been trial tested in schools to obtain values of item facility. The items are designed to assist teachers in the preparation of tests for diagnostic and achievement purposes.

Items from some of ACER's earlier publications have been included in the bank, together with a number of items published by State educational authorities. Addition of this material to the bank enables a wider choice of items for major topic areas.

It is hoped that teachers will produce additional items of their own for this bank, and some notes on test construction and item writing techniques are included later. The ACER would be grateful if teachers forwarded their own original items on to the Council. It is intended that suitable items will be added to the item bank at a later date. Items should be forwarded to:

ACER Chemistry Item Bank,
PO Box 210,
Hawthorn,
Victoria 3122

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THE AUSTRALIAN CHEMISTRY TEST ITEM BANK PROJECT

During 1978 the Chemistry Standing Committee of the Victorian Universities and Schools Examinations Board suggested that a Year 12 course being introduced that year would be assisted by the provision of a collection of test items. Later in 1978, the Victorian Education Department (Secondary Division) agreed to second a practising chemistry teacher to ACER to work on the preparation of a bank of chemistry items, related not only to the Victorian course, but to chemistry courses in each of the other States. The project was placed under the direction of a committee of management comprising:

Dr J. P. Keeves and Dr J. F. Izard—representing the ACER
Mr M. Cropley—representing the Victorian Institute of Secondary Education
Mr R. Fox—representing the VISE Chemistry Subject Committee

Dr I. Wilson—representing the Chemistry Education Association
Mr P. Martin was the secondee responsible for the day-to-day management of the project during 1979
Dr C. Commons was the secondee responsible for the day-to-day management of the project during 1980 and 1981.

Items which were written during 1979 and 1980 were initially published in the *ACER Chemistry Test Item Collection* and in the *ACER Chemistry Test Item Collection Supplement* in order to provide Victorian teachers with an immediate source of items for the Core and Options section of their new Year 12 course, pending publication of the item bank. The current publication contains most of the 542 items in these collections, together with hundreds of items which have not been released previously.

Most of the items included in this publication were written by practising chemistry teachers. After an initial editing, items were reviewed by panels of teachers. These reviewing panels had the task of correcting any mistakes in content, checking the plausibility of distractors, ensuring a uniformity of terminology, and imposing a consistent format which facilitates the answering of questions. Items which were found to have problems that could not be corrected were rejected. The remaining items were re-edited in the light of the reviewing panel's suggestions, and then assembled into trial tests.

Trial testing was conducted to provide empirical evidence on the performance of the items. It also provides basic statistical data, such as the percentage of trial students who responded correctly, as an aid for teachers when selecting specific items from the collection.

Trial testing was performed at the Year 12 level in over 200 secondary schools between the months of August and October in 1979, 1980 and 1981. As far as possible, the trial tests were administered to a sample of students who had previously studied the topics for which the tests were designed. The average sample size was 113 with a range of 78 to 174 students.

Most of the items included in the bank had a point biserial correlation of 0.15 or greater. The point biserial correlation provides a measure of an item's capacity to differentiate more able students from less able students as determined from the total score on the test concerned. Items with a correlation of less than 0.15 have been included where it is believed they would be useful to teachers, and such items have been marked by an asterisk placed beside the facility value in the left hand margin of the text.

The items in the bank are intended to cover the chemistry taught at both Year 11 and Year 12 levels. Since the topics taught at the Year 11 level vary widely between schools within most States, it has only been possible to obtain reliable facility values for items at the Year 12 level. It is anticipated that these data will also provide an indication of the relative difficulties of items for students at the lower level. The practice of including items for year 11 in tests administered to Year 12 students may be a major reason for the low point biserial correlations determined for some items. A low correlation need not necessarily indicate that an item is unsuitable for inclusion in a test.

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USING THE ITEM BANK

1 Uses for the Items

A Production of diagnostic tests

A diagnostic test is one which attempts to identify learning difficulties experienced by students and enables the provision of some form of assistance in overcoming the problems that are identified. Such tests should

(a) contain a comprehensive range of items measuring the objectives of the syllabus area that is being evaluated; and

(b) enable the provision of some form of feedback to the students after they have attempted the items.

The items in the bank have been constructed so that the choice of a particular distractor will allow the teacher to determine the nature of a student's error, and to advise the student of any appropriate remedial work necessary. Common errors could be discussed in class, and written explanations of the correct response (diagnostic aids) might be provided by the teacher. The format used in this publication enables teachers to select items which are most appropriate to the emphasis that they have given to various topics.

B Production of achievement tests

An achievement test is a test designed to measure a student's achievement in a particular syllabus area with a single score. Just as for a diagnostic test, it should contain a comprehensive range of items measuring the objectives of the syllabus area being evaluated. The degree of difficulty of an item at the Year 12 level can be approximately gauged by referring to the item facilities (giving the proportion of students who responded correctly to each item during trial testing). As the collection includes items with a wide range of facilities, it is possible to prepare tests which:

(a) discriminate very well between students in the more able section of the class (using items with a low facility).

(b) discriminate well between students in the weak section of the class (using items with a high facility); and

(c) spread the students over a wide range of marks (using items with a spread of facilities, with an average facility of about 50%).

Note that facility values should be used as a guide to the relative difficulties of items rather than as an absolute standard. The values quoted in the bank are likely to be dependent upon factors such as the nature of the students participating in the trial testing, the time of year at which testing was performed and the emphasis placed on the topics in different schools.

It should be pointed out that the items in this collection alone may not be suitable for assessment of achievement, as some course objectives may be better examined using extended answer test items or practical tasks.

C Models for constructing other items

This bank provides a range of item types which could be used as models for teachers who wish to construct their own items. If items from the bank are supplemented by teacher-written items, it is suggested that the supplementary items be consistent in style. Some rules for constructing multiple choice items are outlined on page ix.

2 Preparation of Tests

In preparing a test, teachers should:

- Identify the particular syllabus areas that are to be evaluated.

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- Select items which appear to evaluate these areas.
- Write items, where necessary, to provide an adequate coverage of the areas.
- Place the items in a logical order. Group items relevant to similar syllabus areas together. If possible, place the easier items early in the test, with the more difficult items towards the end of the test.
- Place items based on the same stimulus material on the one page.
- Ensure that one item does not supply the correct response for another item.
- Check that the items are not ambiguous and that each has a correct response listed.
- Prepare an answer key.
- Ask another teacher to work through the draft, to identify errors and omissions, as well as providing a check on the answer key.

During the trial testing of items, most students completed between six to seven items every ten minutes.

3 Selecting an Item

To facilitate item identification, the items have been classified according to their content area. The content areas are listed in the *Content Axis*, which incorporates an alphanumeric coding to assist the location of items. The content code, facility and answer for each item are given beside the items in the left hand margin. The following example illustrates this format.

S6d-14
20*
E

The most abundant product from the reaction of 2 mol of chlorine with 1 mol of methane in ultraviolet light is likely to be

A CH_3Cl.
B CH_2Cl_2.
C $CHCl_3$.
D CCl_4.
E HCl.

The item is classified under the content code **S6d.** From the *Content Axis*, it can be seen that code **S6d** represents properties of alkanes, where

S = **CARBON CHEMISTRY**
6 = Alkanes
d = Properties

The item is number **14** in this particular content area.

The facility of the item is about 20 per cent (i.e. about 20 per cent of the trial group of students answered this item correctly). All facility values have been rounded to the nearest ten per cent, so that the facility actually calculated from trial test data was in the range 15-24 per cent.

The answer to the item is **E.**

The asterisk beside the facility indicates that the point biserial correlation for this item was less than 0.15 (i.e. the item did not differentiate well between the more able and less able students as determined by the total score on the trial test).

4 Writing Additional Test Items

Multiple-choice items should incorporate the following points:

- The stem and each alternative must read grammatically when taken together.
- The problem posed or the question asked must be clearly set out in the stem.
- The whole item should be as brief as its proper presentation will allow.
- To keep the alternatives brief, incorporate the major part of the idea in the stem. The following example illustrates this point:

Poor

Chemistry is

A a science that is concerned with the relationships and characteristics of matter.
B a science that is concerned with the relationships of living organisms, etc.

Better

Chemistry is a science that is concerned with

A the relationships and characteristic of matter.
B the relationships of living organisms, etc.

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- Avoid a negative stem where possible.

  If unavoidable, either
  (a) emphasize **not**, or
  (b) use: all of the following **except** one. Which one?

- All distractors should be equally attractive to the uninformed, yet the correct alternative must be unequivocally the best.

- Avoid using 'none of the above' as a distractor.
  A preferred alternative is,
  for example: **D** neither **A**, nor **B**, nor **C**.

- All alternatives must be homogeneous in idea and style.
  For example: Do not mix functions and structures.

- Words such as 'all', 'never', 'always', 'only' should not be used indiscriminately.

- Information presented in the stem must be factually correct.

- Distractors must be clearly incorrect, and not merely incomplete.

For a more comprehensive treatment of test construction and item writing, see: Izard, J.F., *Construction and Analysis of Classroom Tests*, ACER 1977.

5 Symbols and Chemical Nomenclature

The topics taught in chemistry at the Year 11 and Year 12 levels in Australia vary considerably between the States and substantial differences may even be detected between the schools within a particular State at the Year 11 level. It is therefore not surprising to find a variety of symbols, units and terminology in use throughout the country.

In order to maintain some degree of internal consistency within this publication it has been necessary to select between the expressions in current use. It is anticipated that teachers will adapt items to their local needs where necessary. Some of the more interesting conventions used in this bank are described below:

(a) The ΔH of a reaction is quoted in units of kJ mol^{-1} rather than kJ. It refers to the enthalpy change *per mole of the reaction as written*. Thus

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l) \qquad \Delta H = -5760 \text{ kJ mol}^{-1}$$

provides the information that an enthalpy change of −5760 kJ results when 2 mol (*not 1 mol*) of butane burns completely in oxygen. At present some teachers prefer to express the unit of ΔH simply as kJ to avoid confusion.

(b) The volume unit m^3(cm^3, dm^3 etc.) has been preferred to the unit of common use the litre. Both units are in use in Australia, but the former unit is chosen by the majority of chemical journals.

(c) Relative atomic masses and relative molecular masses are denoted by the symbols recommended by IUPAC: A_r and M_r, respectively. (It is acceptable to use M_r for entities that are not strictly molecular.)

(d) The symbol K is used for an equilibrium constant, except where there is a possibility of confusion between K_c (concentration basis) and K_p (pressure basis). Since the equilibrium constant for a reaction is derived from the activity of the substances participating in the reaction, strictly speaking K does not have units. Some textbooks in current use introduce K as a constant derived from experimentally determined concentrations and hence include units. Teachers using this approach may wish to attach units to the values of K quoted in some items.

(e) The spelling 'sulfur' has been adopted rather than 'sulphur', in accordance with trends in the world's chemical literature.

(f) IUPAC-recommended names are used for chemical substances where this is practicable. Systematic names are used for small organic molecules (e.g. ethene rather than ethylene, ethanoic acid rather than acetic acid), in line with current practice in most Australian States. In some cases the trivial names are also given.

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CONTENT AXIS
Volumes 1 and 2

Volume 1

A ATOMIC STRUCTURE

- **A1** The nuclear atom
- **A2** Elementary particles
- **A3** Ions
- **A4** Atomic number, Elements
- **A5** Mass number
- **A6** Nuclide notation
- **A7** Isotopes
- **A8** Nuclear binding energy
- **A9** Nuclear reactions
  - **A9a** Balancing nuclear reactions
  - **A9b** Nuclear reactions in stars

B ELECTRONIC STRUCTURE OF ATOMS

- **B1** Shell structure
- **B2** Subshells, Orbitals
- **B3** Pauli principle
- **B4** Electronic configuration of atoms
- **B5** Emission and absorption spectra
  (see also **R4b** *Flame tests)*
- **B6** Ionization energy
  - **B6a** Definition
  - **B6b** Periodic variation
  - **B6c** Successive ionization energies (evidence for shells)

C THE PERIODIC TABLE

- **C1** Historical development
- **C2** Organization of the periodic table
  (see also **Z1** *Transition metal characteristics)*
- **C3** Dependence of properties on electronic structure
- **C4** Periodic properties of elements
  (see also **B6** *Ionization energy*
  E6 *Electronegativity)*
  - **C4a** Trends across periods
    (see also **Z3** *Metal hydrides*
    Z4 *Metal oxides)*

D THE MOLE AND CHEMICAL FORMULAE

- **D1** Relative atomic mass
- **D2** Mass spectra
- **D3** The mole
- **D4** The Avogadro constant
- **D5** Molar mass
- **D6** Percentage composition
- **D7** Law of definite (multiple) proportions
- **D8** Empirical formulae
- **D9** Molecular formulae

E MOLECULAR COMPOUNDS

- **E1** Electronic structure and formulae
- **E2** Common molecular compounds

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- **E3** Electronic structure of molecules
- **E4** Molecular shapes
- **E5** Bond dissociation energy
- **E6** Electronegativity
- **E7** Bond polarity
- **E8** Melting temperature and intermolecular bond strength
- **E9** Dispersion forces
- **E10** Permanent dipoles, Hydrogen bonds Ion-dipole bonding (see **Z2** Metal complexes)
- **E11** Properties of molecular compounds
  (see also **F2e** *Properties of ionic compounds*
  F4 *Miscellaneous bonding items)*

F INFINITE ARRAYS

- **F1** Covalent network solids
- **F2** Ionic lattice solids
  - **F2a** Electrovalencies and formulae
  - **F2b** Electronic structure and formulae
  - **F2c** The ionic bond
  - **F2d** Common ionic compounds
  - **F2e** Properties of ionic compounds
- **F3** Metallic solids
  (see also **Z** *Metals)*
  - **F3a** The metallic bond
  - **F3b** Common metallic solids
  - **F3c** Properties of metals
  - **F3d** Alloys
- **F4** Miscellaneous bonding items

G GASES

- **G1** Kinetic theory of gases
- **G2** Molecular speeds
- **G3** Relationship between pressure and volume
- **G4** Relationship between temperature and volume (or pressure)
- **G5** Molar volume
- **G6** General gas equation
- **G7** Density
- **G8** Partial pressures
- **G9** Vapour pressure
- **G10** Boiling
- **G11** Non-ideal gases

H SOLUTIONS

- **H1** Dissociation
  (see also **W2** *Water)*
- **H2** Ionization
  (see also **N** *Acids)*
- **H3** Conductivity of electrolytes
  (see also **F2c** *Properties of ionic compounds*
  N3 *Strengths of acids and bases)*
- **H4** Saturation
- **H5** Solubility
- **H6** Factors affecting solubility
  (see also **W2** *Water)*
- **H7** Concentration (molarity)
- **H8** Solubility of gases in liquids

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I SURFACES

- I1 Interfaces
- I2 Suspensions, Colloids
- I3 Emulsions
- I4 Monolayers
- I5 Surface energy, Surface tension
- I6 Hydrophobic and hydrophilic substances
- I7 The liquid-solid interface (wetting, meniscii)
- I8 Surfactants (detergency, froth flotation)
  (see also **F15** *Fats, Oils, Soaps, Detergents*
  Z9a *Mineral dressing (froth flotation))*
- I9 Young's equation

J STOICHIOMETRY

- J1 Law of Conservation of Mass
- J2 Chemical equations
  (see also **O3** *Balancing redox equations)*
- J3 Mole - mole relationships
- J4 Mole - mass relationships
- J5 Mass - mass relationships
  - **J5a** Percentage yield
- J6 Reactions in solution
  (see also **N8** *Stoichiometric calculations involving acid-base reactions)*
- J7 Reactions in the gas phase
  (see also **S6d** *Properties of alkanes)*
- J8 Mass - gas volume relationships
- J9 Mass - gas pressure relationships

K HEAT OF REACTION

- K1 Exothermic and endothermic reactions
- K2 Uses of exothermic reactions
- K3 Temperature changes during reactions
- K4 Units of energy
- K5 Enthalpy change
- K6 Calorimetry
- K7 Thermochemical cycles

L CHEMICAL EQUILIBRIUM

- L1 Nature of the equilibrium state
- L2 The equilibrium constant, K_c
- L3 Calculations in equilibrium systems
- L4 Effect of addition of reactants or products
- L5 Effect of volume or pressure changes
- L6 Effect of temperature changes
  (see also **U2b** *Preparation of ammonia*
  U3c *Properties of nitrogen oxides*
  U4a *Preparation of nitric acid*
  X2 *Sulfur oxides*
  X3 *Sulfuric acid)*
- L7 Effect of catalysts
  (see also **M5** *Catalysis)*
- L8 Manipulation of equilibrium constants
- L9 Heterogeneous equilibria

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M REACTION RATES

- **M1** Factors affecting rate
- **M2** Units of rate
- **M3** Stoichiometry and reaction rates
- **M4** Activation energy
- **M5** Catalysis
  (see also **L7** *Effect of catalysts)*
- **M6** Reaction mechanisms
  - **M6a** Rate laws, Order, Molecularity
  - **M6b** Electrophiles, Nucleophiles
  - **M6c** Electrophilic substitution reactions
  - **M6d** Nucleophilic substitution reactions
  - **M6e** Free radical reactions
    (see also **S6d** *Properties of alkanes)*

N ACIDS AND BASES

- **N1** The acid-base concept
- **N2** H_3O^+ concentration in acid solutions
- **N3** Strengths of acids and bases
  Dilution of acids (see **H7** Concentration (molarity))
- **N4** Polyprotic acids
- **N5** Amphiprotic substances
- **N6** Ionic product, K_w
- **N7** pH
- **N8** Stoichiometric calculations involving acid-base reactions
  (see also **J** *Stoichiometry)*
- **N9** Equivalence point, End point
  Standard solutions (see **R4e** Standard solutions, Primary standards)
- **N10** Sources of errors in titrations
- **N11** Titration curves
- **N12** Indicators
- **N13** Buffers
- **N14** Acidity constant, K_a

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Volume 2

O REDOX REACTIONS

- **O1** Oxidation numbers
- **O2** The redox concept
- **O3** Balancing redox equations
- **O4** Electron transfer in redox reactions
- **O5** Activity series of metals
- **O6** Strengths of oxidants and reductants
- **O7** Prediction of reaction from $E°$ values
  (see also **P3** *Prediction of reactions from $E°$ values*
  Q3 *Prediction of reactions from $E°$ values)*

P ELECTROCHEMICAL CELLS

- **P1** Basic principles
- **P2** Standard electrode potentials ($E°$)
- **P3** Prediction of reaction from $E°$ values
- **P4** Determination of cell EMF
- **P5** Calculations using the Faraday constant
- **P6** Secondary cells
- **P7** Fuel cells

Q ELECTROLYSIS

- **Q1** Basic principles
- **Q2** Examples of electrolysis
  (see also **Z9e** *Electrowinning*
  Z12 *Copper extraction*
  Z14 *Zinc extraction*
  Z15 *Aluminium extraction)*
- **Q3** Prediction of reactions from $E°$ values
- **Q4** Ratios of products
- **Q5** Calculations using the Faraday constant
- **Q6** Avogadro's constant from electrolysis data

R MEASUREMENT AND CHEMICAL TECHNIQUES

- **R1** Measurement
  - **R1a** Standard form
  - **R1b** Significant figures
  - **R1c** Uncertainty
  - **R1d** Random and systematic errors
    (see also **J** *Stoichiometry*
    N10 *Sources of errors in titrations)*
- **R2** Purification techniques
  (see also **Z9** *Metal extraction techniques)*
  - **R2a** Filtration
  - **R2b** Use of a separating funnel
  - **R2c** Distillation
    (see also **S2c** *Fractional distillation of hydrocarbons)*
  - **R2d** Recrystallization
  - **R2e** Miscellaneous purification items
- **R3** Quantitative and qualitative analysis

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R4 Analysis techniques

- **R4a** Chromatography
- **R4b** Flame tests
  Emission and absorption spectroscopy (see **B5**)
- **R4c** Melting temperature determination
- **R4d** Gravimetric analysis
  (see also **J** *Stoichiometry)*
- **R4e** Standard solutions, Primary standards
  Titrations (see **J6** Reactions in solution, **N** Acids and Bases, **R4e** Standard solutions, Primary standards)

S CARBON CHEMISTRY

S1 The element

S2 Hydrocarbons

- **S2a** Composition
- **S2b** Occurrence (oil, coal, natural gas)
- **S2c** Fractional distillation
- **S2d** Cracking

S3 Functional groups

S4 Homologous series

S5 Isomerism

S6 Alkanes

- **S6a** Nature
- **S6b** Nomenclature
- **S6c** Structure
- **S6d** Properties
  (see also **M6e** *Free radical reactions)*

S7 Alkenes

- **S7a** Nature
  Preparation (see **S2d** Cracking)
- **S7b** Structure
- **S7c** Properties

S8 Alkynes

S9 Aromatic hydrocarbons

- **S9a** Nature
- **S9b** Structure
- **S9c** Properties

S10 Halohydrocarbons

- **S10a** Preparation (see **M6e** Free radical reactions, **S6d** Akane properties, **S7c** Alkene properties)

S11 Alcohols

- **S11a** Nature
  Preparation (see **S7c** Alkene properties, **S10** Halohydrocarbons)
- **S11b** Properties

S12 Aldehydes, Ketones

- **S12a** Nature
- **S12b** Nomenclature
- **S12c** Structure
- **S12d** Preparation
  (see also **S11b** *Alcohol properties)*
- **S12e** Properties

S13 Carboxylic acids

- **S13a** Nature
  Preparation (see **S11b** Alcohol properties)
- **S13b** Properties
  (see also **U7** *Amides)*

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S14 Esters

- **S14a** Nature
- **S14b** Nomenclature
  Preparation (see **S13b** Carboxylic acid properties)
- **S14c** Properties

S15 Fats, Oils, Detergents

- **S15a** Nature, Structure
- **S15b** Properties
  (see also **I8** *Surfactants (detergency, froth floation))*

S16 Carbohydrates

- **S16a** Sugars
- **S16b** Respiration
- **S16c** Photosynthesis
- **S16d** Starch, Cellulose
- **S16e** Fermentation

S17 Insecticides

S18 Polymers
(see also **S16d** *Starch, Cellulose*
T2 *Silicon polymers*
U9 *Proteins*
U10 *Nucleic acids)*

- **S18a** Monomers, Copolymers, Polymer properties
- **S18b** Addition polymers
- **S18c** Condensation polymers
- **S18d** Cross linked polymers
- **S18e** Rubber

S19 Carbon dioxide

- **S19a** Production
  (see also **S16b** *Respiration*
  S16e *Fermentation)*
- **S19b** Properties

S20 Carbonates, Hydrogen carbonates

- **S20a** Occurrence
- **S20b** Properties, Uses
- **S20c** Hard water

S21 Carbon monoxide

T SILICON CHEMISTRY

T1 Silanes

T2 Silicon polymers
(see also **S18** *Polymers)*

T3 Silicon carbide
(see also **F1** *Covalent network solids)*

T4 Silicon dioxide

- **T4a** Occurrence
- **T4b** Structure
  (see also **F1** *Covalent network solids)*
- **T4c** Properties

T5 Silicates

- **T5a** Occurrence
- **T5b** Glass
- **T5c** Clays, Ceramics, Portland cement

U NITROGEN CHEMISTRY

U1 The element

- **U1a** Occurrence
- **U1b** Production
- **U1c** Properties

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U2 Ammonia

- **U2a** Structure
- **U2b** Preparation
  (see also **L** *Chemical equilibrium)*
- **U2c** Properties
  (see also **E10** *Permanent dipoles, Hydrogen bonds*
  Z2c *Ion-dipole bonds*
  Z6 *Metal hydroxides)*

U3 Nitrogen oxides

- **U3a** Occurrence
- **U3b** Preparation
- **U3c** Properties
  (see also **L** *Chemical equilibrium)*

U4 Nitric acid

- **U4a** Preparation
- **U4b** Properties

U5 The nitrogen cycle

U6 Amines

- **U6a** Preparation
- **U6b** Properties

U7 Amides
(see also **U9c** *Urea)*

U8 Amino acids

- **U8a** Identity, Structure
- **U8b** Properties
- **U8c** Role in biochemical systems

U9 Proteins

- **U9a** Structure
- **U9b** Properties
- **U9c** Urea
- **U9d** Enzymes

V PHOSPHORUS CHEMISTRY

V1 The element

- **V1a** Occurrence
- **V1b** Structure
- **V1c** Preparation
- **V1d** Properties

V2 Phosphorus oxides and oxo acids

V3 Phosphates

W OXYGEN CHEMISTRY

W1 The element

W2 Water
(see also **H** *Solutions*
N *Acids and bases*
E10 *Permanent dipoles, Hydrogen bonds)*

W3 Hydrogen peroxide

Carbon dioxide (see **S19**)
Carbon monoxide (see **S21**)
Silicon dioxide (see **T4**)
Nitrogen oxides (see **U3**)
Phosphorus oxides (see **V2**)
Sulfur oxides (see **X2**)
Metal oxides (see **Z4**)

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X SULFUR CHEMISTRY

- X1 The element
- X2 Sulfur oxides
- X3 Sulfuric acid
- X4 Hydrogen sulfide

Y HALOGEN CHEMISTRY

- Y1 The elements
  - Y1a Structure
    Preparation (see O2 Examples of electrolysis)
  - Y1b Properties
- Y2 Hypohalites
- Y3 Metal halides

Z METALS

(see also **F3** *Metallic solids)*

- Z1 Transition metal characteristics
  (see also **C2** *Organization of the periodic table)*
- Z2 Metal complexes
  - Z2a Ligands
  - Z2b Formulae
  - Z2c Ion-dipole bonds
    (see also **U2c** *Ammonia properties*
    W2 *Water)*
  - Z2d Solubility
  - Z2e Stability
- Z3 Metal hydrides
- Z4 Metal oxides
  - Z4a Preparation
  - Z4b Properties
- Z5 Corrosion
- Z6 Metal hydroxides
  Metal sulfides (see **X4** Hydrogen sulfide)
  Activity series of metals (see **O5**)
- Z7 Occurrence of metals and metal ores
- Z8 Ease of extraction of metals
- Z9 Extraction techniques
  - Z9a Mineral dressing (froth flotation)
    (see also **I8** *Surfactants (detergency, froth flotation))*
  - Z9b Roasting
  - Z9c Leaching
  - Z9d Solvent extraction
  - Z9e Electrowinning
- Z10 Iron extraction
  - Z10a Methods
  - Z10b Types of iron
- Z11 Steel manufacture
  (see also **F3d** *Alloys)*
- Z12 Copper extraction
  - Z12a Pyrometallurgical methods
  - Z12b Electrorefining
  - Z12c Hydrometallurgical methods, Electrowinning
    (see also **Q2** *Examples of electrolysis)*

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Z13 Nickel extraction
(see also **Q5** *Calculations using the Faraday constant)*
Z14 Zinc extraction
Z15 Aluminium extraction
(see also **Q5** *Calculations using the Faraday constant)*
Z16 Uranium extraction

APPENDIX

A number of items published by Australian educational authorities have been included in the bank in order to provide a more complete coverage of each of the topics in the *Content Axis*. These items and their sources are listed below. In some cases items have been modified to suit the format of the bank. Other items have been modified in accordance with suggestions from teachers or in the light of trial test data. ACER is grateful for the permission of each authority to use these items in this publication.

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O REDOX REACTIONS

O1 Oxidation numbers

O1-1 80 **A**

In which of the following compounds does the underlined element have an oxidation number of +2?

A $\underline{Zn}(OH)_4^{2-}$ **B** $\underline{Cr}O_2Cl_2$ **C** $\underline{N}O_2^-$ **D** $\underline{C}H_3OH$

O1-2 80* **E**

The oxidation number of chlorine in $KClO_4$ is

A −1. **B** −3. **C** −7. **D** +3. **E** +7.

O1-3 60 **D**

In which one of the following conversions does the oxidation number of an element decrease by 3?

A $NO \rightarrow NO_3^-$
B $PH_4^+ \rightarrow P$
C $MnO_2 \rightarrow MnO_4^-$
D $CrO_4^{2-} \rightarrow Cr^{3+}$

O1-4 80 **B**

Consider the following equation, which represents a reaction in the extraction of chromium from its ore:

$$2Fe_2O_3 \cdot Cr_2O_3 + 4Na_2CO_3 + 3O_2 \rightarrow 2Fe_2O_3 + 4Na_2CrO_4 + 4CO_2$$

Which one of the following statements about the oxidation states of the substances is correct?

A The iron has been reduced from a +3 to a +2 state.
B The chromium has been oxidized from a +3 to a +6 state.
C The carbon has been oxidized from a +2 to a +4 state.
D There is no change in the oxidation state of any of the substances in the reaction.

O1-5 60 **A**

In which of the following compounds does phosphorus show the lowest oxidation state?

A PH_4Br **B** $POBr_3$ **C** PF_3 **D** PCl_5 **E** $Ca_3(PO_4)_2$

O2 The redox concept

O2-1 60 **C**

Which one of the following is an example of an oxidation-reduction reaction?

A $2K_2CrO_4 + H_2SO_4 \rightleftharpoons K_2Cr_2O_7 + K_2SO_4 + H_2O$
B $CaC_2 + 2H_2O \rightleftharpoons Ca(OH)_2 + C_2H_2$
C $2Na + Cl_2 \rightleftharpoons 2NaCl$
D $BaSO_3 + 2HCl \rightleftharpoons BaCl_2 + H_2O + SO_2$

O2-2 40 **A,B,E**

Which **one or more** of the following reactions of nitrogen oxides are redox reactions?

A $2NO + O_2 \rightarrow 2NO_2$
B $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$
C $2NO_2 \rightarrow N_2O_4$
D $N_2O_3 + H_2O \rightarrow 2HNO_2$
E $3NO \rightarrow N_2O + NO_2$

O2-3 80 **C**

Concentrated sulfuric acid is able to act as an oxidising agent.
Which one of the following equations illustrates this ability?

A $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
B $NaCl(s) + H_2SO_4(aq) \rightarrow NaHSO_4(aq) + HCl(aq)$
C $Zn(s) + 2H_2SO_4(aq) \rightarrow ZnSO_4(aq) + 2H_2O(l) + SO_2(g)$
D $2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$

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O2-4 90 **B**

In which of the following equations is the underlined species undergoing oxidation?

A $2\underline{Cu^{2+}} + 4I^- \rightarrow 2CuI + I_2$
B $Sn^{4+} + \underline{Fe} \rightarrow Sn^{2+} + Fe^{2+}$
C $H_2S + \underline{Cl_2} \rightarrow 2HCl + S$
D $\underline{Cu(OH)_2} + 2H^+ \rightarrow Cu^{2+} + 2H_2O$

O2-5 60 **C**

Four incomplete half reactions are given below. In which case is a reduction occurring?

A $SO_3 \rightarrow SO_4^{2-}$
B $Mn^{2+} \rightarrow MnO_4^-$
C $O_2 \rightarrow H_2O_2$
D $CrO_4^{2-} \rightarrow Cr_2O_7^{2-}$

O2-6 20 **A**

A reduction reaction may often involve the

A addition of hydrogen.
B removal of hydrogen.
C addition of hydrogen ion.
D removal of hydrogen ion.

O2-7 80 **A**

The process of black and white photography depends upon the reaction

$$2Ag^+ + 2Br^- \rightarrow 2Ag + Br_2$$

which is initiated by light.

Which of the following species is reduced in this reaction?

A Ag^+ **B** Br^- **C** Ag **D** Br_2

O2-8 70 **B**

Zinc powder reacts with sulfur, and this reaction may be represented by the equation:

$$Zn + S \rightarrow ZnS$$

In this reaction,

A zinc is the oxidizing agent.
B sulfur is reduced.
C sulfur is the reducing agent.
D zinc is reduced.

The next two items refer to the following information

Metal *M* reacts with water evolving hydrogen gas.

O2-9 70 **C**

M is behaving as

A an acid.
B a base.
C a reducing agent.
D an oxidizing agent.

O2-10 40 **B**

Given further information that:

I the reaction of *M* with water is extremely vigorous,
II *M* is in period 4,
III *M* forms a solid hydrogen carbonate,

the probable identity of *M* is

A calcium. **B** potassium. **C** magnesium. **D** sodium.

O2-11 80 **D**

Methane, a major component of natural gas, burns in air according to the equation

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

The oxidizing agent in this reaction is

A carbon. **B** hydrogen. **C** methane. **D** oxygen.

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O2-12 40 **A**

Iodine reacts with hydroxide ions according to the reaction

$$3I_2(aq) + 6OH^-(aq) \rightleftharpoons IO_3^-(aq) + 5I^-(aq) + 3H_2O(l)$$

Which two species are acting as oxidizing agents?

A $I_2(aq)$ and $IO_3^-(aq)$
B $OH^-(aq)$ and $I^-(aq)$
C $IO_3^-(aq)$ and $OH^-(aq)$
D $I^-(aq)$ and $I_2(aq)$

O2-13 40 **C**

Foam rubber may be produced from the oxygen released when hydrogen peroxide decomposes according to the equation

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

In this reaction hydrogen peroxide acts as

A an oxidizing agent only.
B a reducing agent only.
C both an oxidizing agent and a reducing agent.
D neither an oxidizing agent nor as a reducing agent.

O2-14 50 **D**

The equation for the reaction between permanganate ions and sulfite ions in acid solution is

$$2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$$

Which one of the following statements is true?

A The permanganate ion is behaving as a reductant in this reaction.
B As the reaction proceeds the pH of the solution decreases.
C The hydrogen ions are reduced to water during the reaction.
D The sulfite ions are oxidized during the reaction.

The next two items refer to the following information:

The following equations represent reactions between some related chemical species.

I (i) $2H_2S + O_2 \rightarrow 2H_2O + 2S$
(ii) $H_2S + Cl_2 \rightarrow 2HCl + S$

II (i) $4FeO + O_2 \rightarrow 2Fe_2O_3$
(ii) $2FeCl_2 + Cl_2 \rightarrow 2FeCl_3$
(iii) $2FeS + S \rightarrow Fe_2S_3$

O2-15 50 **A**

From the equations given in I, it can be said that

A H_2S is being oxidized in both reactions.
B H_2S is being oxidized in (i), and reduced in (ii).
C H_2S is being reduced in (i), and oxidized in (ii).
D O_2 is a stronger oxidizing agent than Cl_2, since each O_2 molecule reacts with two H_2S molecules.

O2-16 70 **D**

From the equations given in II, it can be said that

A iron compounds can be reduced by non-metallic elements.
B oxygen, chlorine, and sulfur are all strong reducing agents.
C iron(II) compounds are more easily oxidized than iron metal.
D oxidation of iron(II) compounds to iron(III) compounds may be caused by elements other than oxygen.

O2-17 30 **A,B**

Nitrous acid, HNO_2, can act as both an oxidant and a reductant. Which **one or more** of the following could result from HNO_2 acting as an oxidant?

A NH_3 **B** N_2 **C** HNO_3 **D** N_2O_5 **E** N_2O_3

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O3 Balancing redox equations

O3-1 80* **A**

The half reaction for the reduction of NO_3^- to N_2O can be represented by the equation

$$aNO_3^- + bH^+ + 8e^- \rightarrow cN_2O + dH_2O$$

where the values of the coefficients a and b are, respectively,

A 2 and 10. **B** 2 and 5. **C** 1 and 4. **D** 1 and 5.

O3-2 80 **E**

The permanganate ion, MnO_4^-, can oxidize H_2S to elemental sulfur, according to the following equations:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$
$$H_2S \rightarrow S + 2H^+ + 2e^-$$

When the redox reaction occurs, the mole ratio of MnO_4^- reacting to S produced is

A 1:1. **B** 1:2. **C** 5:1. **D** 5:2. **E** 2:5.

O3-3 40 **B**

The equation for the following reaction, which occurs in acidic solution, has been left unbalanced.

$$_MnO_4^- + _SO_3^{2-} + _H_3O^+ \rightarrow _Mn^{2+} + _H_2O + _SO_4^{2-}$$

Coefficients for MnO_4^- and SO_3^{2-} which balance the equation are, respectively,

A 1 and 6. **B** 2 and 5. **C** 3 and 4. **D** 4 and 3. **E** 5 and 2.

O3-4 20* **C**

When sulfur is boiled with sodium hydroxide solution, the initial reaction results in the formation of sulfide ions, S^{2-}, and sulfite ions, SO_3^{2-}. The mole ratio of the species

$$S : S^{2-} : SO_3^{2-}$$

in the balanced equation will be, respectively,

A 2 : 1 : 1.
B 3 : 1 : 2.
C 3 : 2 : 1.
D 4 : 1 : 3.
E 4 : 3 : 1.

O3-5 30 **D**

When hydrogen sulfide gas is passed into a solution of iron(III) nitrate, a pale yellow precipitate is formed and the solution becomes pale green.

The equation for this reaction is

A $H_2S + Fe^{3+} + 3H_2O \rightarrow H_2 + S + Fe(OH)_3 + 3H^+$.
B $3H_2S + Fe(NO_3)_3 \rightarrow Fe(OH)_3 + 3HNO_2 + 3S$.
C $3H_2S + 2Fe^{3+} \rightarrow Fe_2S_3 + 6H^+$.
D $H_2S + 2Fe^{3+} \rightarrow 2H^+ + S + 2Fe^{2+}$.

O4 Electron transfer in redox reactions

The next two items refer to the following information

One method for analysing the amount of alcohol in a person's blood is based on the reaction of dichromate ions with ethanol.

$$2Cr_2O_7^{2-} + 3CH_3CH_2OH + 16H^+ \rightarrow 4Cr^{3+} + 3CH_3COOH + 11H_2O$$

O4-1 90 **B**

As the reaction proceeds the oxidation number of the chromium atom changes from

A +7 to +3. **B** +6 to +3. **C** +7 to −3. **D** −2 to +3.

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O4-2
40
B

If the reaction produces 1 mol of Cr^{3+} ions, the number of electrons transferred between the atoms would have been (given $N_A = 6 \times 10^{23}$)

A 7.2×10^{24}.
B 1.8×10^{24}.
C 4.5×10^{23}.
D 2.0×10^{23}.
E 1.5×10^{23}.

O4-3
40
B

Addition of 0.20 mol of zinc metal to a solution containing 0.10 mol of Ag^+ ions results in the formation of silver metal. The number of electrons transferred during this reaction is (given $N_A = 6.0 \times 10^{23}$)

A 3.0×10^{22}.
B 6.0×10^{22}.
C 1.2×10^{23}.
D 6.0×10^{23}.
E 1.2×10^{24}.

O4-4
60
B

ClO_2 is prepared for use in water treatment plants by the reduction of $NaClO_3$.

$$2NaClO_3 + SO_2 + H_2SO_4 \rightarrow 2ClO_2 + 2NaHSO_4$$

When 1 mol of ClO_2 is prepared, the amount of electrons transferred in the reaction is

A ½ mol.
B 1 mol.
C 2 mol.
D 4 mol.

O5 Activity series of metals

O5-1
50
A

No noticeable reaction occurred when a strip of metal was added to dilute hydrochloric acid.

Of the following, the metal is most likely to be

A copper.
B potassium.
C zinc.
D iron.

O5-2
40
B

The activity of the metal barium is between that of sodium and potassium. It is likely that

A barium would displace potassium from potassium chloride solution.
B barium would displace hydrogen gas from cold water.
C barium would displace sodium from sodium chloride solution.
D barium ions in solution would readily oxidize zinc metal to zinc ions.

O5-3
80
C

Four metallic elements (G, L, M, R) were tested to determine their relative activities. Each metal was added to a 2 M solution of HCl, two of them (G and L) were added to cold water, and two of them (G and M) were added to an aqueous solution of R^+. The observed results are summarized in the table below.

	G	*L*	*M*	*R*
Reaction with cold water	No reaction	Slowly dissolved	Not tested	Not tested
Reaction with 2 M HCl	Dissolved, with formation of a gas	Dissolved, with formation of a gas	No reaction	No reaction
Reaction of metal with R^+(aq) solution	Dissolved, with formation of a precipitate	Not tested	Dissolved, with formation of a precipitate	Not tested

The order of **decreasing** activity (most reactive first) of the four metals is

A L, G, R, M
B G, L, M, R
C L, G, M, R.
D L, R, G, M.
E R, M, G, L.

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O5-4 50 **B**

Which one of the following mixtures could **not** be used in the laboratory to produce hydrogen gas?

A tin and dilute hydrochloric acid
B copper and dilute sulfuric acid
C zinc and dilute hydrochloric acid
D iron and dilute sulfuric acid

O5-5 60 **A**

Which one of the following ions in aqueous solution would **not** be precipitated as a metal by addition of magnesium metal?

A Ca^{2+} **B** Cu^{2+} **C** Sn^{2+} **D** Ag^{+}

O5-6 50* **A**

A small piece of silver is placed in a solution containing both magnesium nitrate and copper(II) nitrate. Which one of the following occurs?

A nothing
B the silver dissolves and only copper is precipitated
C the silver dissolves and only magnesium is precipitated
D a mixture of magnesium and copper forms on the silver
E hydrogen bubbles form on the surface of the silver

O6 Strengths of oxidants and reductants

O6-1 50* **D**

Metallic zinc displaces silver ions from solution to give metallic silver and zinc ions.
Metallic zinc displaces hydrogen ions from solution to give gaseous hydrogen and zinc ions.
Metallic silver does not displace hydrogen ions from solution.

In which one of the following are the substances listed in the order, weakest reductant to strongest reductant?

A Zn, H_2, Ag
B Zn^{2+}, H^{+}, Ag^{+}
C Ag^{+}, H^{+}, Zn^{2+}
D Ag, H_2, Zn

O6-2 60 **D**

A student made the following observations in the laboratory:

i Clean *X* metal did not react with 1 M X^{2+}(aq).
ii Clean *Y* metal dissolved in 1 M Z^{2+}(aq) and crystals of *Z* metal appeared.
iii Clean Z metal did not react with 1 M X^{2+}(aq).

The order of strength as a reducing agent of the three metals is

A $X > Y > Z$. **B** $X > Z > Y$. **C** $Y > Z > X$. **D** $Y > X > Z$.

O6-3 40* **C**

Ce^{4+} will oxidize HCl. Br_2 will oxidize Fe^{2+}. Cl_2 will oxidize HBr. Fe^{3+} will oxidize HI. It follows that Fe^{2+} can be oxidized by

A Cl_2 and I_2, but not by Ce^{4+}.
B Ce^{4+} and I_2, but not by Cl_2.
C Ce^{4+} and Cl_2, but not by I_2.
D Cl_2, but not by Ce^{4+} or I_2.
E Ce^{4+}, but not by Cl_2 or I_2.

O6-4 70 **D**

Metal *X* and *Z* both displace hydrogen from dilute HCl. Metal *Y* is displaced from a solution of one of its salts by metal *Z*. Only metal *X* displaces hydrogen from water and solutions of salts of the other two metals.

The order of **decreasing** reducing strength of the metals is

A *YZX*. **B** *ZYX*. **C** *XYZ*. **D** *XZY*.

O6-5 70 **D**

Tin displaces copper metal from $CuSO_4$ solutions and cadmium displaces tin metal from $SnCl_2$ solutions.

Which of the following reactions would be expected to occur to a significant extent?

A $Sn^{2+} + Cu \rightarrow Sn + Cu^{2+}$
B $Cd^{2+} + Cu \rightarrow Cd + Cu^{2+}$
C $Sn + Cd^{2+} \rightarrow Sn^{2+} + Cd$
D $Cd + Cu^{2+} \rightarrow Cd^{2+} + Cu$

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The next three items refer to the following information

Four hypothetical metallic elements A, B, C and D form soluble nitrates having formulae ANO_3, $B(NO_3)_2$, CNO_3 and $D(NO_3)_3$.

Strips of each of the four metals were immersed in 0.1 M aqueous solutions of the other metal nitrates, and the following observations recorded.

1 Metal B underwent reaction in all solutions.
2 Metal A only reacted with CNO_3.

O6-6 50 **A** Metal D would react with

A ANO_3 and CNO_3 only.
B $B(NO_3)_2$ and CNO_3 only.
C ANO_3 and $B(NO_3)_2$ only.
D ANO_3, $B(NO_3)_2$ and CNO_3.

O6-7 30 **A** In order of **increasing** strength as **reducing** agents, the metals are

A C, A, D and B.
B B, C, D and A.
C A, D, C and B.
D B, D, A and C.

O6-8 40 **B** Which one of the following ions is the **weakest** oxidizing agent?

A A^+ **B** B^{2+} **C** C^+ **D** D^{3+}

The next two items refer to the following information

The half equations below represent the reduction reactions of three substances A^{3+}, B^{2+}, C_2.

$$A^{3+}(aq) + e^- \rightarrow A^{2+}(aq)$$
$$B^{2+}(aq) + 2e^- \rightarrow B(s)$$
$$C_2(aq) + 2e^- \rightarrow 2C^-(aq)$$

Pairs of the six species [$A^{3+}(aq)$, $A^{2+}(aq)$, $B^{2+}(aq)$, $B(aq)$, $C_2(aq)$, $C^-(aq)$] were mixed in test tubes, and if any observable reaction occurred, the results were noted. **Some** of these results are given in the table. The combinations indicated by I, II and III in the table were not investigated.

Oxidant \ Reductant	$A^{2+}(aq)$	$B(s)$	$C^-(aq)$
$A^{3+}(aq)$	—	√	I
$B^{2+}(aq)$	II	—	III
$C_2(aq)$	×	√	—

√ observable reaction occurs.
× no observable reaction occurs.
– not tested

O6-9 20 **A** In which of the following would it be expected that an observable reaction would occur?

A I only
B II only
C I and II only
D I and III only
E I and II and III

O6-10 40 **B** Which of the following gives the correct order of strength of the oxidants, from weakest to strongest?

A $C_2 < B^{2+} < A^{3+}$
B $B^{2+} < C_2 < A^{3+}$
C $A^{3+} < B^{2+} < C_2$
D $C_2 < A^{3+} < B^{2+}$

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O7 Prediction of reaction from E^0 values

O7-1 30 **A**

0.10 mol of Ag and 0.10 mol of Cu are added to a solution containing 0.10 mol of Ag^+ and 0.10 mol of Cu^{2+} ions. When reaction is complete the solution will contain

(given $E^0_{Ag^+,\,Ag} = +0.80$ V; $E^0_{Cu^{2+},\,Cu} = +0.34$ V)

A 0.15 mol of Cu^{2+}.
B 0.20 mol of Cu^{2+}.
C 0.15 mol of Ag^+.
D 0.20 mol of Ag^+.

The next four items refer to the following information

Consider the standard potentials for the following reactions:

Half Reaction	E^0/*volt*
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	− 0.14
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+ 1.30
$Be^{2+}(aq) + 2e^- \rightarrow Be(s)$	− 1.85
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+ 0.15
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	− 0.74

O7-2 70 **B**

The weakest oxidizing agent in the following set is

A Sn^{2+}. **B** Be^{2+}. **C** Sn. **D** Be. **E** Co^{3+}.

O7-3 50 **B**

The weakest reducing agent in the following set is

A Be^{2+}. **B** Co^{2+}. **C** Be. **D** Co^{3+}. **E** Sn.

O7-4 70* **A**

The species which appears in the set as both an oxidizing and reducing agent is

A Sn^{2+}. **B** Co^{3+}. **C** Cr. **D** Sn.

O7-5 80 **C**

Which of the following reactions would proceed substantially to the right?

A $2Co^{2+} + Sn^{2+} \rightarrow 2Co^{3+} + Sn$
B $Sn^{2+} + Be^{2+} \rightarrow Be + Sn^{4+}$
C $Be + Sn^{2+} \rightarrow Be^{2+} + Sn$
D $2Cr^{3+} + 3Sn^{2+} \rightarrow 3Sn^{4+} + 2Cr$

O7-6 60 **B**

A piece of nickel is placed in a solution of copper(II) sulfate.

Which one of the following statements is **incorrect** (given $E^0_{Ni^{2+},\,Ni} = -0.23$ V; $E^0_{Cu^{2+},\,Cu} = +0.34$ V)?

A Copper is precipitated.
B Copper ions are oxidized.
C Nickel dissolves into solution.
D There is no increase in electrical charge in the solution.

O7-7 50 **C**

Two possible redox reactions of sulfurous acid are represented by the half-equations

$$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l) \quad E^0 = +0.20 \text{ V}$$

$$H_2SO_3(aq) + 4H^+(aq) + 4e^- \rightarrow S(s) + 3H_2O(l) \quad E^0 = +0.45 \text{ V}$$

Sulfurous acid in aqueous solution is added in turn to H_2S ($E^0_{S,\,H_2S} = +0.14$ V) and acidified $K_2Cr_2O_7$, ($E^0_{Cr_2O_7^{2-},\,Cr^{3+}} = +1.36$ V).

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The result is

A the sulfurous acid oxidizes both the dichromate and H_2S solutions.
B both the dichromate and H_2S solutions oxidize the sulfurous acid solution.
C the sulfurous acid oxidizes the H_2S solution and reduces the dichromate solution.
D the sulfurous acid reduces the H_2S solution and oxidizes the dichromate solution.

The next two items refer to the following table of E^0 values.

$Br_2 + 2e^- \rightarrow 2Br^-$	$E^0 = +1.087$ V
$Cl_2 + 2e^- \rightarrow 2Cl^-$	$E^0 = +1.358$ V
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	$E^0 = +1.33$ V
$I_2 + 2e^- \rightarrow 2I^-$	$E^0 = +0.535$ V
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	$E^0 = +1.491$ V

O7-8 30 **B**

From this table, we would predict that

A bromine molecules will be oxidised to bromide ions by a solution containing iodide ions.
B dichromate ions will not oxidise iodide ions unless an acid solution is present.
C permanganate ions will only reduce a chlorine solution in the presence of H^+ ions.
D dichromate ions will reduce chlorine solutions, but not a solution of permanganate ions.

O7-9 70 **C**

The E^0 for the reaction $2NO_3^- + 10H^+ + 8e^- \rightarrow N_2O + 5H_2O$ is +1.18 V.
This means that an acidic solution of NO_3^- would be reduced by solutions of

A Cl^- or Cr^{3+}.
B MnO_4^- or $Cr_2O_7^{2-}$.
C Br^- or I^-.
D MnO_4^- or Br^-.

O7-10 30 **D**

Suppose that you want to keep a solution containing Fe^{2+} ions free of Fe^{3+} ions usually formed by atmospheric oxidation. Which of the following procedures would you recommend (given $E^0_{Ag^+,\,Ag} = +0.80$ V, $E^0_{Zn^{2+},\,Zn} = -0.76$ V, $E^0_{Fe^{3+},\,Fe^{2+}} = +0.77$ V, $E^0_{Fe^{2+},\,Fe} = -0.44$ V)?

A add $Ag^+(aq)$ **B** add $Zn^{2+}(aq)$ **C** add Ag **D** add Fe

O7-11 70 **A**

Use the following standard electrode potentials to determine which of the species listed will be reduced by hydrogen sulphide.

$Cl_2 + 2e^- \rightarrow 2Cl^-$	$E^0 = +1.36$ V
$Br_2 + 2e^- \rightarrow 2Br^-$	$E^0 = +1.07$ V
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	$E^0 = +0.77$ V
$I_2 + 2e^- \rightarrow 2I^-$	$E^0 = +0.53$ V
$S + 2H^+ + 2e^- \rightarrow H_2S$	$E^0 = +0.14$ V
$Fe^{2+} + 2e^- \rightarrow Fe$	$E^0 = -0.41$ V

A Cl_2, Br_2, Fe^{3+}, I_2
B Cl^-, Br^-, Fe^{2+}, I^-
C Fe^{2+} only
D Fe only

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30

The next three items refer to the following information

Half reaction	E^0/*volt*
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	−0.13
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	−0.41
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	−0.41
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	−0.76
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	−0.90
$Sr^{2+}(aq) + 2e^- \rightarrow Sr(s)$	−2.89

O7-12 60 **D**

On the basis of the E^0 values given, which of the following lists contains only metals which you would predict could **not** react directly with the hydrogen ions in a 1 M solution of HCl?

A Cu, Cr
B Sr, Zn, Cr, Sn, Pb
C Ag, Cu, Pb, Sn
D Ag, Cu

O7-13 80 **A**

The strongest oxidizing agent in the above list of species is

A Ag^+. **B** Ag. **C** Sr. **D** Sr^{2+}.

O7-14 50 **B**

In which one of the following systems would you expect an appreciable chemical reaction to occur?

A Silver metal is added to a solution of silver nitrate.
B Iron metal is added to a solution of iron(III) nitrate.
C Copper metal is added to a solution of copper(II) nitrate.
D Lead metal is added to a solution of lead(II) nitrate.
E None of these.

O7-15 70 **D**

Consider the following data:

	E^0/*volt*
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$	+1.09
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + S(s) + 2e^- \rightarrow H_2S(g)$	+0.14

Which one of the following equations represents a reaction that occurs spontaneously?

A $2Fe^{3+}(aq) + 2Cl^-(aq) \rightarrow 2Fe^{2+}(aq) + Cl_2(g)$
B $2H^+(aq) + S(s) + Sn^{2+}(aq) \rightarrow H_2S(g) + Sn^{4+}(aq)$
C $Br_2(aq) + 2Cl^-(aq) \rightarrow 2Br^-(aq) + Cl_2(g)$
D $2Fe^{3+}(aq) + Sn^{2+}(aq) \rightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$

O7-16 30 **A**

Given the data:

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$, $E^0 = +0.34$ V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$, $E^0 = -0.13$ V
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$, $E^0 = -0.27$ V

Which of the following reactions has the **smallest** equilibrium constant?

A $Ni^{2+}(aq) + Cu(s) \rightleftharpoons Ni(s) + Cu^{2+}(aq)$
B $Ni^{2+}(aq) + Pb(s) \rightleftharpoons Ni(s) + Pb^{2+}(aq)$
C $Ni(s) + Pb^{2+}(aq) \rightleftharpoons Ni^{2+}(aq) + Pb(s)$
D $Cu(s) + Pb^{2+}(aq) \rightleftharpoons Cu^{2+}(aq) + Pb(s)$
E $Cu^{2+}(aq) + Pb(s) \rightleftharpoons Cu(s) + Pb^{2+}(aq)$

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The next three items refer to the following information

Strips of the metals Pb, Fe, Cu and of two other metals which we label *X* and *Y* are each dipped into 0.1 M solutions of $X(NO_3)_2$, $Fe(NO_3)_2$, $Cu(NO_3)_2$, $Pb(NO_3)_2$, and $Y(NO_3)_2$.

The results of these tests are tabulated according to the following scheme:

+ indicates a deposit formed on the strip.
− indicates no deposit formed on the strip.
0 indicates that the experiment was not performed.

Cation Solution	Metal Strip				
	Pb	Fe	Cu	*X*	*Y*
Fe^{2+}	−	0	−	+	−
Cu^{2+}	+	+	0	+	+
Y^{2+}	+	+	−	+	0
Pb^{2+}	0	+	−	+	−
X^{2+}	−	−	−	0	−

O7-17 50 **D** Which of the five metals is the strongest reducing agent?

A Pb **B** Fe **C** Cu **D** *X* **E** *Y*

O7-18 70 **B** Which of the five metal ions is the strongest oxidizing agent?

A Fe^{2+} **B** Cu^{2+} **C** Y^{2+} **D** Pb^{2+} **E** X^{2+}

O7-19 40 **C** A possible value for E^0 for the system $X^{2+}(aq) + 2e^- \rightarrow X(s)$ is

(given $E^0_{Fe^{2+},\,Fe} = -0.41$ V; $E^0_{Cu^{2+},\,Cu} = +0.34$ V; $E^0_{Pb^{2+},\,Pb} = -0.13$ V)

A +0.25 V. **B** +0.70 V. **C** −0.70 V. **D** −0.25 V.

O7-20 60 **D** Consider the following standard redox potentials:

$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$ $\quad E^0 = +1.77$ V
$O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq)$ $\quad E^0 = +0.68$ V

The above data predict that hydrogen peroxide spontaneously decomposes forming hydrogen and oxygen, but bottles of hydrogen peroxide are commercially available.

This is because

A the reaction is endothermic and must be initiated by heating.
B the equilibrium constant for the reaction is very small.
C half cell potentials are temperature dependent.
D the rate of decomposition of hydrogen peroxide is low.

O7-21 60 **C** Consider the following data:

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ $\quad E^0 = +1.40$ V
$MnO_2(s) + 4H^+(aq) + 2e^- \rightarrow Mn^{2+}(aq) + 2H_2O(l)$ $\quad E^0 = +1.23$ V

On the basis of the E^0 values it might be predicted that no appreciable reaction would occur between $Cl^-(aq)$ and $MnO_2(s)$. However a common method for preparing chlorine gas in the laboratory is to react MnO_2 with concentrated HCl.

The major factor causing this apparent contradiction is that

A E^0 values do not allow predictions concerning the rate of reactions.
B loss of Cl_2 gas from the system forces the equilibrium in the forward direction.
C E^0 values are determined under standard state conditions.
D equilibrium constants are affected by temperature.

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P ELECTROCHEMICAL CELLS

P1 Basic principles

P1-1 80 **C**

A salt bridge in an electrochemical cell allows

A passage of electrons through the salt bridge to the cathode.
B free mixing of the reactants in each half cell.
C migration of ions towards different half cells.
D the formation of oppositely charged solutions in the half cells.

P1-2 40 **D**

The EMF of a new dry cell is normally 1.5 V. If, in a particular cell, the species involved in the cell reaction were at equilibrium, the EMF of that cell would be

A more than 1.5 V.
B 1.5 V.
C between 1.5 V and 0 V.
D 0 V.

P1-3 60 **B**

Which one of the following materials would be **least** suitable for use as an electrode material in a standard Fe^{3+}, Fe^{2+} half cell?

A platinum
B iron
C carbon
D silver

P2 Standard electrode potentials (E^0)

P2-1 50 **A**

A cell with an EMF of 0.40 V has the cell reaction

$$2H^+(aq) + 2Cr^{2+}(aq) \rightleftharpoons 2Cr^{3+}(aq) + H_2(g)$$

If the concentrations of ions were 1 M and the pressure of H_2 were 101325 Pa, then the E^0 for the half reaction

$$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$$

would be

A −0.40 V. **B** −0.20 V. **C** +0.20 V. **D** +0.40 V.

P2-2 20 **A**

If a value of −1.0 V was assigned to the standard hydrogen half cell instead of the currently accepted value of zero, the EMF of a particular electrochemical cell would be

A unchanged.
B increased by 1.0 V.
C increased by 2.0 V.
D decreased by 1.0 V.

P3 Prediction of reactions from E^0 values

P3-1 50 **C**

Which of the following species would act as an oxidizing agent in a galvanic cell composed of Ni^{2+}, Ni and Pb^{2+}, Pb standard half cells

(given $E^0_{Ni^{2+}, Ni} = -0.23$ V, $E^0_{Pb^{2+}, Pb} = -0.13$ V)?

A Ni^{2+} **B** Ni **C** Pb^{2+} **D** Pb

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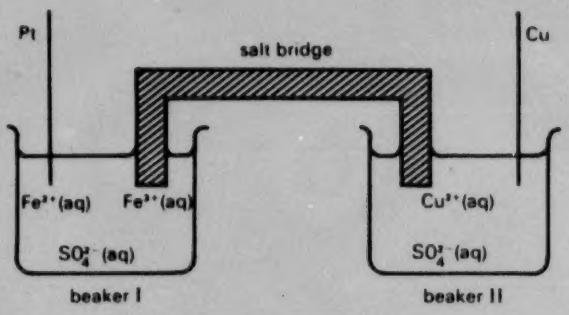
The next two items refer to the following diagram and data



$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ $\quad E^0 = +0.77$ V

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $\quad E^0 = +0.34$ V

P3-2 50 B

Concentrations are 1 M with respect to the ions listed.

For the above system

A there will be no electron flow in the wire.

B electrons will flow in the wire from Cu to Pt.

C electrons will flow in the wire from Pt to Cu.

D electrons will flow through the salt bridge from the $Cu^{2+}(aq)$ solution to the $Fe^{2+}(aq)$ solution.

E electrons will flow through the salt bridge from the $Fe^{2+}(aq)$ solution to the $Cu^{2+}(aq)$ solution.

P3-3 60 A

For the system illustrated, the electrode polarity will be

A Pt positive, Cu negative.

B Pt negative, Cu positive.

C Pt and Cu both at zero potential.

P3-4 50 A

An electrochemical cell is formed by coupling a Ni^{2+}, Ni standard half cell with a S, S^{2-} standard half cell.

Which of the following reactions would occur at the cathode

(given $E^0_{Ni^{2+},\,Ni} = -0.23$ V, $E^0_{S,\,S^{2-}} = -0.51$ V)?

A $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$.

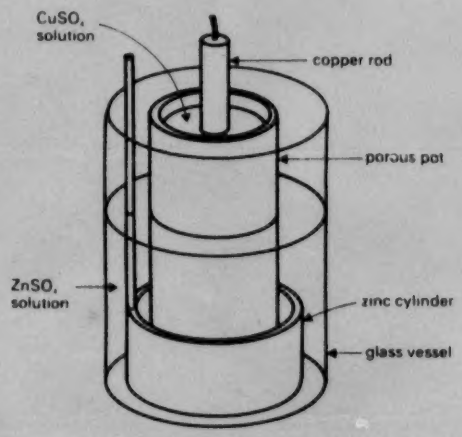
B $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$.

C $S(s) + 2e^- \rightarrow S^{2-}(aq)$.

D $S^{2-}(aq) \rightarrow S(s) + 2e^-$.

P3-5 70 A

The diagram shows a simple primary cell (the Daniell cell).



$E^0_{Cu^{2+},\,Cu} = +0.34$ V

$E^0_{SO_4^{2-},\,SO_2} = +0.20$ V

$E^0_{Zn^{2+},\,Zn} = -0.76$ V

In this cell, the reactant involved at the cathode is

A Cu^{2+}.

B H_2O.

C Zn^{2+}.

D SO_4^{2-}.

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P3-6 60 **D**

Silver oxide cells are used for hearing aids and electric watches. The cell reaction is

$$Ag_2O + Zn + H_2O \rightarrow 2Ag + Zn(OH)_2$$

At the cathode of this cell

A zinc metal is reduced.
B zinc metal is oxidized.
C silver ions are oxidized.
D silver ions are reduced.

P4 Determination of cell EMF

P4-1 70 **A**

An electrochemical cell is formed by coupling Ag^+, Ag and Sn^{2+}, Sn standard half cells.

$$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s) \quad E^0 = -0.14 \text{ V}$$
$$Ag^+(aq) + e^- \rightarrow Ag(s) \quad E^0 = +0.80 \text{ V}$$

The EMF of the cell would be approximately

A 0.94 V. **B** 0.66 V. **C** 1.74 V. **D** 1.46 V.

P4-2 30 **A**

The EMF of a cell composed of Pb^{2+}, Pb and $Br_2(aq)$, Br^- standard half cells is 1.22 V and the lead electrode is negative.

What would be the EMF of a cell composed of Br_2, Br^- and $I_2(s)$, I^- standard half cells?

(given $E^0_{Pb^{2+}, Pb} = -0.13$ V, $E^0_{I_2(s), I^-} = +0.54$ V)

A 0.55 V **B** 0.81 V **C** 1.63 V **D** 1.89 V

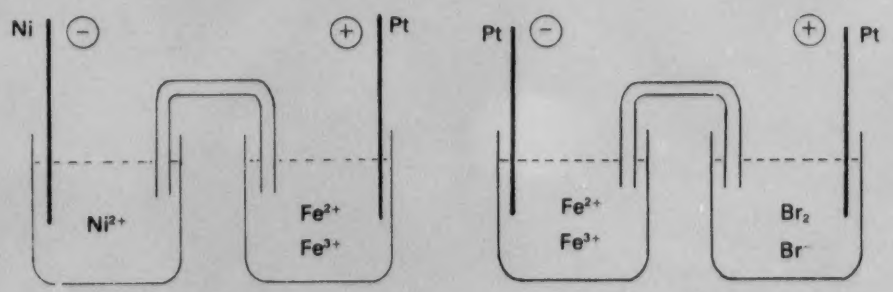
P4-3 60 **A**

The EMF of a cell composed of a Sn^{4+}, Sn^{2+} half cell and a Cl_2, Cl^- standard half cell is 1.25 V. A cell composed of an I_2, I^- half cell and a Cl_2, Cl^- standard half cell has an EMF of 0.78 V. In each cell the Cl_2 acts as the oxidant. If a cell were formed from the I_2, I^- half cell and the Sn^{4+}, Sn^{2+} half cell, its EMF would be

A 0.47 V.
B 2.03 V.
C 0.16 V.
D unable to be determined from this information.

The next two items refer to the following information

Consider the two standard electrochemical cells below.



P4-4 40 **A**

The polarities of the electrodes indicate that the strongest reducing agent present is

A Ni. **B** Fe^{3+}. **C** Br_2. **D** Br^-. **E** Ni^{2+}.

P4-5 70 **C**

Which of the following combinations of half cells would generate the greatest EMF?

A Ni^{2+}, Ni and Fe^{3+}, Fe^{2+}
B Fe^{3+}, Fe^{2+} and Br_2, Br^-
C Ni^{2+}, Ni and Br_2, Br^-
D Fe^{3+}, Fe^{2+} and Fe^{3+}, Fe^{2+}

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P4-6 60 C

Which one of the standard electrodes whose half cell reactions are given below would give the largest EMF when paired with a standard calomel electrode (E^0 = +0.24 V)?

A $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ $\quad E^0 = +0{\cdot}77$ V

B $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $\quad E^0 = -0{\cdot}23$ V

C $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ $\quad E^0 = -0{\cdot}76$ V

D $Ag^{+}(aq) + e^- \rightarrow Ag(s)$ $\quad E^0 = +0{\cdot}80$ V

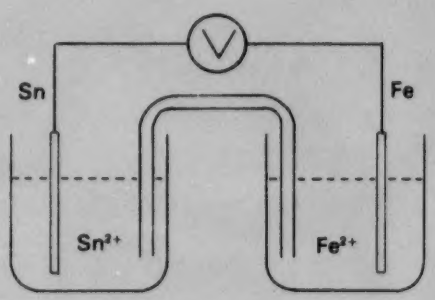
P4-7 60 C

Given the following standard redox potentials

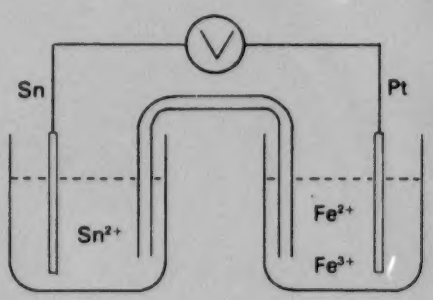
Half reaction	E^0/*volt*
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77

Indicate which of the following cells would generate the greatest EMF if the concentration of all ions is 1M.

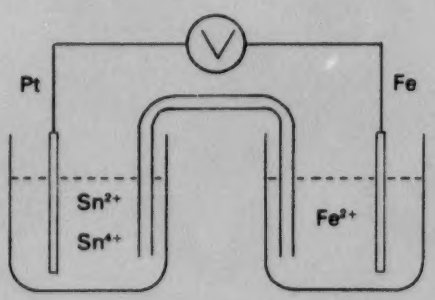
A



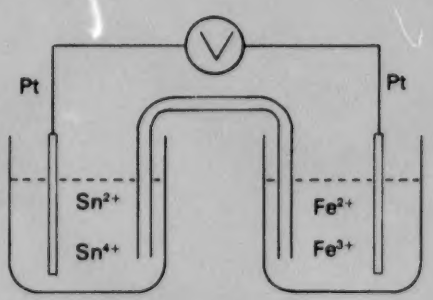
C



B



D



P5 Calculations using the Faraday constant

P5-1 60 B

A fully charged car battery can supply 1.8×10^5 C. The cell reaction is

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

What mass of lead (A_r = 207) is consumed when the car battery runs down (given F = 96500 C mol^{-1})?

A $\dfrac{1.8 \times 10^5 \times 207}{96500}$ g

B $\dfrac{1.8 \times 10^5 \times 207}{2 \times 96500}$ g

C $1.8 \times 10^5 \times 96500 \times 207$ g

D $\dfrac{2 \times 1.8 \times 10^5 \times 207}{96500}$ g

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The next three items refer to the following information

The cell reaction occurring in a particular galvanic cell as current is drawn is

$$Ag_2O(s) + Zn(s) + H_2O(l) \rightarrow 2Ag(s) + Zn(OH)_2(s)$$

The cell potential is 1.50 V.

P5-2 60 **D**

In the galvanic cell referred to above, zinc forms the

A positive electrode, and is reduced.
B positive electrode, and is oxidized.
C negative electrode, and is reduced.
D negative electrode, and is oxidized.

P5-3 60 **C**

The galvanic cell is to be used to work a hearing aid that draws a continuous current of 0.100 mA. What amount of Ag_2O would be needed to keep the cell running continuously for 12 weeks (7257600 s)?

(Faraday constant, $F = 96500$ C mol^{-1})

A $\dfrac{2 \times 0.100 \times 10^{-3} \times 1.50}{96500} \times 7257600$ mol

B $\dfrac{0.100 \times 10^{-3} \times 1.50}{96500} \times 7257600$ mol

C $\dfrac{0.100 \times 10^{-3}}{2 \times 96500} \times 7257600$ mol

D $\dfrac{2 \times 0.100 \times 10^{-3}}{96500} \times 7257600$ mol

P5-4 60 **A**

Given that the electrolyte in the cell is a 1 M KOH aqueous solution and the silver oxide/silver electrode in alkaline solution has an E^0 of +0.34 V, then the E^0 of the zinc hydroxide/zinc electrode in alkaline solution is

A −1.16 V. **B** −1.84 V. **C** +1.16 V. **D** +1.84 V.

P6 Secondary cells

P6-1 90 **D**

A lead-acid accumulator is classed as a secondary cell because it

A contains a liquid electrolyte rather than a paste electrolyte.
B is composed of primary cells connected in series.
C is capable of delivering a large current for a short period of time.
D can be recharged by the application of an external EMF.

P6-2 50 **D**

Car batteries are of the lead-acid type. The overall reaction which occurs as the battery discharges is

$$Pb(s) + PbO_2(s) + 4H^+ + 2SO_4^{2-} \rightarrow 2PbSO_4 + 2H_2O$$

In the *recharging* process,

A the pH of the solution in the battery increases.
B all Pb^{2+} ions in the battery are oxidised to Pb^{4+} ions.
C the lead plates in the battery dissolve as Pb^{2+} ions are produced.
D Pb^{2+} ions are either oxidised or reduced depending on the electrode they are near.

P6-3 50 **D**

The overall reaction for a lead-acid accumulator is

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)\,.$$

Given the following data:

$PbO_2(s) + 4H^+(aq) + 2e^-$	$\rightarrow Pb^{2+}(aq) + 2H_2O(l)$	$E^0 = +1.46$ V
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$	$\rightarrow PbSO_4(s) + 2H_2O(l)$	$E^0 = +1.69$ V
$PbSO_4(s) + 2e^-$	$\rightarrow Pb(s) + SO_4^{2-}(aq)$	$E^0 = -0.36$ V
$Pb^{2+}(aq) + 2e^-$	$\rightarrow Pb(s)$	$E^0 = -0.13$ V

then the approximate potential that could be expected from the cell is

A 1·33 V. **B** 1·59 V. **C** 1·82 V. **D** 2·05 V.

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P6-4 40 **B**

As a lead-acid accumulator is *discharging*, the pH of the electrolyte solution in the battery

A decreases steadily.
B increases steadily.
C remains constant.
D initially decreases, then remains constant.

P6-5 60 **D**

The nickel-cadmium cell commonly used in electronic calculators has as its overall cell reaction

$$Ni_2O_3(s) + 3H_2O(l) + Cd(s) \rightleftharpoons Cd(OH)_2(s) + 2Ni(OH)_2(s)$$

and has an EMF of 1·3 V.

To recharge this cell it would be necessary to

A apply a potential of 1·3 V across the cell, with the Cd electrode connected to the positive terminal of the power source.
B apply a potential of 1·3 V across the cell, with the Cd electrode connected to the negative terminal of the power source.
C apply a potential of more than 1·3 V across the cell, with the Cd electrode connected to the positive terminal of the power source.
D apply a potential of more than 1·3 V across the cell, with the Cd electrode connected to the negative terminal of the power source.

P7 Fuel cells

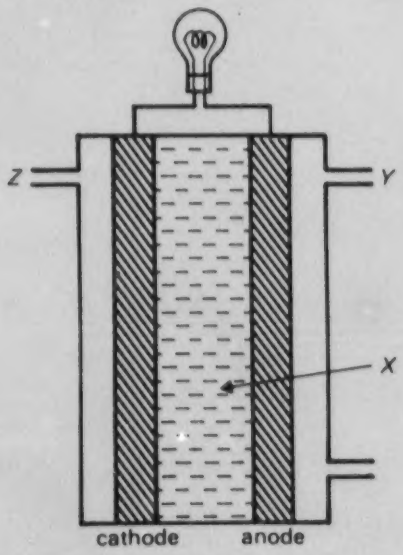
P7-1 50 **C**

Which of the following statements best describes the function of an H_2–O_2 fuel cell?

A It converts thermal energy from a chemical reaction to electrical energy.
B It stores electrical energy produced from the reaction of H_2 and O_2.
C It converts energy from the oxidation of H_2 directly to electrical energy.
D It promotes reaction between H_2 and O_2 using an external energy source.

P7-2 30 **B**

The diagram below shows a cross-section through a functioning H_2–O_2 fuel cell.



Which **one or more** of the following statements is correct?

A The anode consists of a strip of platinum.
B Label X refers to a solution of an electrolyte.
C Label Y refers to the oxygen gas outlet.
D Label Z refers to the hydrogen gas inlet.

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P7-3
20*
C

During the operation of a hydrogen-oxygen fuel cell using an acid medium, there will be

A an increase in the number of H^+ ions but $[H^+]$ will remain constant.
B a decrease in the number of H^+ ions but $[H^+]$ will gradually increase.
C a constant number of H^+ ions but $[H^+]$ will gradually decrease.
D an increase in the number of H^+ ions and $[H^+]$.
E a decrease in the number of H^+ ions and $[H^+]$.

The next two items refer to the following information

A fuel cell can be constructed which exploits the following redox pairs.

$$CO_2(g) + 8H^+(aq) + 8e^- \rightarrow CH_4(g) + 2H_2O(l) \qquad E^0 = +0.17\ V$$
$$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l) \qquad E^0 = +1.23\ V$$

P7-4
60
D

Which of the following processes would occur at the positive electrode of the cell?

A production of methane
B production of hydrogen ions
C oxidation of methane
D consumption of oxygen

P7-5
70
B

If the concentrations of ions were 1 M and gas pressures were 101325 Pa, the maximum EMF which could be obtained from such a cell would be

A 1.40 V. **B** 1.06 V. **C** 2.29 V. **D** 2.63 V.

The next two items refer to the following information

Methanol has been used as a fuel in an experimental fuel cell. The electrode reactions were:

$$CH_3OH + 5OH^- \rightarrow HCOO^- + 4H_2O + 4e^-$$
$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

P7-6
50*
B

During the operation of the cell the pH of the solution near the anode would be

A increasing. **B** decreasing. **C** unchanged.

P7-7
20
D

If 70% of the energy produced in the cell reaction was converted to electrical energy, the amount of methanol required in order to produce 3.0 faradays of electricity would be

A $\frac{70}{100} \times \frac{4}{1} \times \frac{3.0}{1}$ mol.
B $\frac{70}{100} \times \frac{1}{4} \times \frac{1}{3.0}$ mol.
C $\frac{70}{100} \times \frac{4}{1} \times \frac{1}{3.0}$ mol.
D $\frac{100}{70} \times \frac{1}{4} \times \frac{3.0}{1}$ mol.
E $\frac{100}{70} \times \frac{4}{1} \times \frac{3.0}{1}$ mol.

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Q ELECTROLYSIS

Q1 Basic principles

Q1-1
70
C

When comparing galvanic cells with electrolysis cells, it is true to say that

A the anode is positive, and the cathode is negative in each case.
B reduction occurs at the negative electrode in a galvanic cell.
C reduction occurs at the cathode in both cases.
D oxidation occurs at the cathode in an electrolysis cell.

Q1-2
80
B

Which one of the following statements about reactions in galvanic cells and in electrolysis cells is correct?

A Oxidation occurs at the anode of galvanic cells and at the cathode of electrolysis cells.
B Galvanic cell reactions are spontaneous whereas electrolysis reactions are driven by external power supplies.
C Galvanic cell reactions are redox reactions whereas electrolysis reactions are deposition reactions.
D Oxidation occurs at the positive electrode in both galvanic and electrolysis cells.

Q1-3
60
A

The polarity of a cathode is

A negative in an electrolysis cell but positive in a galvanic cell.
B positive in an electrolysis cell but negative in a galvanic cell.
C negative in both electrolysis and galvanic cells.
D positive in both electrolysis and galvanic cells.

Q1-4
90
D

Which of the following best identifies the cathode in an electrolysis cell?

A the electrode at which cations are discharged
B the electrode at which no gas can be evolved
C the electrode at which OH^- ions are produced
D the electrode at which reduction occurs

Q2 Examples of electrolysis

Q2-1
50
D

During electrolysis of molten ionic compounds, electron transfer reactions occur at the electrodes of the cell. If molten calcium chloride is electrolysed using inert electrodes, reactions represented by the following equations occur:

$$Ca^{2+} + 2e^- \rightarrow Ca$$
$$2Cl^- \rightarrow Cl_2 + 2e^-$$

Concerning this electrolysis, which of the following statements is correct?

A Oxidation occurs at the negative electrode.
B Ca^{2+} ions are reduced at the positive electrode.
C Electrons pass through the metallic part of the circuit from Ca^{2+} ions to the Cl^- ions.
D The cations in the electrolyte undergo reduction.

Q2-2
50
C

Consider the electrolysis of molten potassium iodide, using unreactive electrodes.

Which one of these equations represents the reaction at the positive electrode?

A $K \rightarrow K^+ + e^-$
B $K^+ + e^- \rightarrow K$
C $2I^- \rightarrow I_2 + 2e^-$
D $I_2 + 2e^- \rightarrow 2I^-$

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Q2-3 50 **E**

The half reaction

$$F_2(g) + 2e^- \rightarrow 2F^-(aq)$$

has an $E^\ominus$ of +2.87 volts.

Fluorine gas is prepared by electrolysis of molten salts rather than by electrolysis of aqueous solutions because

A metal fluorides are insoluble in water.
B fluoride ions are difficult to reduce.
C fluoride ions decompose water into its elements.
D fluorine gas reacts violently with water.
E oxygen gas is evolved in preference to fluorine in aqueous solutions.

Q2-4 60 **B**

Concentrated aqueous solutions of sodium chloride (brine) are electrolysed in diaphragm cells or mercury cells to produce three products of commercial importance. The products are

A sodium metal, chlorine and hydrogen.
B chlorine, sodium hydroxide and hydrogen.
C oxygen, sodium metal and chlorine.
D hydrogen, sodium hydroxide and oxygen.

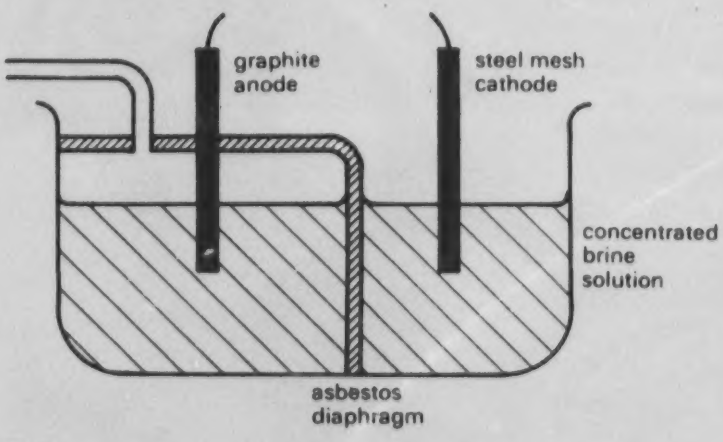
Q2-5 50 **B**

Electrolysis of a concentrated solution of sodium chloride is an important industrial process. In this process, which uses a potential difference of 5 V,

A oxygen is produced at the anode and chlorine is produced at the cathode.
B chlorine is produced at the anode and hydrogen is produced at the cathode.
C oxygen is produced at the anode and hydrogen is produced at the cathode.
D OH^- ions are produced at the anode and chlorine is produced at the cathode.
E chlorine is produced at the cathode and sodium is produced at the anode.

Q2-6 50 **C**

The diagram shows a simplified representation of a commercial electrolysis cell — the Nelson Cell.



When this cell is used in industry, the products are

A chlorine and oxygen.
B chlorine and hydrogen.
C chlorine, hydrogen and sodium hydroxide.
D sodium hydroxide and hydrogen.

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Q2-7 40 **B**

Two main methods are used for the industrial electrolysis of concentrated aqueous solutions of sodium chloride (brine): the mercury cathode method and the diaphragm method. In the mercury cathode method the reaction which occurs at the **positive** electrode is best represented by

A $Na^+ + e^- \rightarrow Na$.
B $2Cl^- \rightarrow Cl_2 + 2e^-$.
C $Hg^{2+} + 2e^- \rightarrow Hg$.
D $2H_2O + 2e^- \rightarrow 2OH^- + H_2$.

Q2-8 30 **A**

During the electrolysis of 0.1 M sodium chloride solution

A hydroxide ions are formed at the cathode.
B chloride ions move randomly in solution.
C sodium ions migrate towards the anode.
D sodium metal is deposited at the cathode.

Q2-9 30 **A**

In the electrolysis of a very dilute solution of lithium chloride, using a potential difference of 5 V,

A hydrogen is produced at the cathode, and oxygen is produced at the anode.
B hydrogen is produced at the cathode, and chlorine is produced at the anode.
C lithium is produced at the cathode, and chlorine is produced at the anode.
D chlorine is produced at the cathode, and hydrogen is produced at the anode.
E oxygen is produced at the cathode, and hydrogen is produced at the anode.

Q2-10 40* **C**

When 0.01 M hydrochloric acid undergoes electrolysis using inert electrodes

A oxygen gas is produced at the positive electrode as chloride ions are oxidized.
B oxygen gas is produced at the negative electrode as chloride ions are oxidized.
C oxygen gas is produced at the positive electrode as water molecules are oxidized.
D hydrogen gas is produced at the positive electrode as water molecules are oxidized.

Q2-11 60 **B**

When dilute sulfuric acid undergoes electrolysis using inert electrodes, gases are produced at each electrode. The reactions occurring at these electrodes are

	at anode	*at cathode*
A	$2H^+ + 2e^- \rightarrow H_2$	$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
B	$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$	$2H^+ + 2e^- \rightarrow H_2$
C	$H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$	$2H^+ + 2e^- \rightarrow H_2$
D	$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$	$H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$

Q2-12 80* **D**

When caustic soda solution (NaOH) is electrolysed, the reactions occurring at the anode and cathode may be represented by the following equations:

anode $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
cathode $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

From this, it can be concluded that

A OH^- ions are reduced.
B equal numbers of hydrogen and oxygen molecules are produced in a given time.
C in this reaction, hydrogen gas is the reducing agent.
D oxidation occurs at the anode.

Q2-13 40 **D**

The process used for preparing pure copper in commercial quantities involves essentially the electrolysis of copper sulfate solution using copper electrodes. During this process

A copper metal is deposited on the positive electrode.
B copper ions migrate towards the anode.
C hydrogen gas is given off at the negative electrode.
D the mass of the anode decreases.

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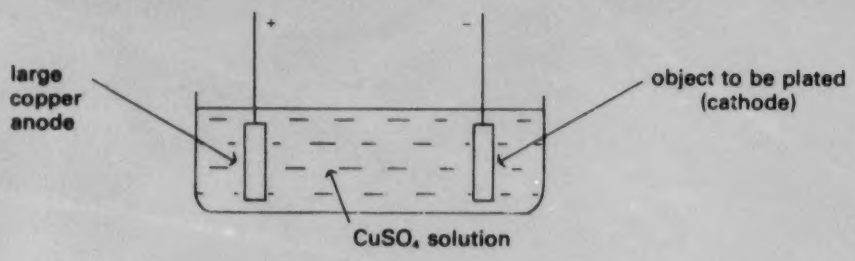
42

The next two items refer to the following information

The diagram below represents a cell used for copper plating.



The cell contains 1 dm^3 of 1.00 M copper(II) sulfate solution. 0.20 mol of electrons is passed through the cell.

Q2-14 70 **C**

The mass of copper plated on the cathode is (given A_r Cu = 63.5)

A 0.20 × 63.5 g.
B 2 × 0.20 × 63.5 g.
C $\frac{1}{2}$ × 0.20 × 63.5 g.
D 2 × 2 × 0.20 × 63.5 g.

Q2-15 30 **D**

The concentration of copper(II) ions in solution after the passage of the charge is

A 0.60 M. **B** 0.80 M. **C** 0.90 M. **D** 1.00 M.

Q2-16 20 **C,D**

Which **one or more** of the following elements may be extracted commercially from electrolysis of aqueous solutions?

A sodium **B** aluminium **C** copper **D** chlorine

Q3 Prediction of reactions from E^0 values

Q3-1 30 **A**

Given the following standard electrode potentials

Half reaction	E^0 */volt*
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$H_2O(l) + e^- \rightarrow OH^-(aq) + \frac{1}{2}H_2(g)$	−0.83
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	−2.38
$Na^+(aq) + e^- \rightarrow Na(s)$	−2.71

which **one or more** of the following procedures could be used to produce magnesium metal?

A electrolysis of molten $MgCl_2$
B addition of sodium to $MgCl_2$ solution
C electrolysis of $MgCl_2$ solution
D addition of silver to $MgCl_2$ solution

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Q3-2 30 **A**

A solution of $Pb(NO_3)_2$ is electrolysed using copper electrodes.

Half reaction	E^0 */volt*
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.35
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	−0.13
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	−0.83

The initial cell reaction which is likely to occur to the greatest extent is

A $Cu + Pb^{2+} \rightarrow Cu^{2+} + Pb$.

B $Cu + 2H_2O \rightarrow Cu^{2+} + H_2 + 2OH^-$.

C $2H_2O \rightarrow 2H_2 + O_2$.

D $2Pb^{2+} + 2H_2O \rightarrow 2Pb + O_2 + 4H^+$.

The next two items refer to the following information:

Half Reaction	E^0 */volt*
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	+1.23
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$	+0.16
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	−1.66

$AlCl_3$ and $CuCl_2$ are dissolved in water so that the concentration of Al^{3+} and Cu^{2+} are each 1.0 M. An electric current is passed between two carbon electrodes placed in the solution.

Q3-3 40 **D**

Which one of the following reactions would occur at the negative electrode?

A $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

B $Al^{3+} + 3e^- \rightarrow Al$

C $2Cl^- \rightarrow Cl_2 + 2e^-$

D $Cu^{2+} + 2e^- \rightarrow Cu$

E $Cl_2 + 2e^- \rightarrow 2Cl^-$

Q3-4 50 **A**

After current was passed through the solution for some time, a new reaction began at the negative electrode. This reaction would be

A $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$.

B $Cu \rightarrow Cu^{2+} + 2e^-$.

C $Cu^{2+} + e^- \rightarrow Cu^+$.

D $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$.

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The next two items refer to the following information.

Two cells are connected as shown in the diagram below.

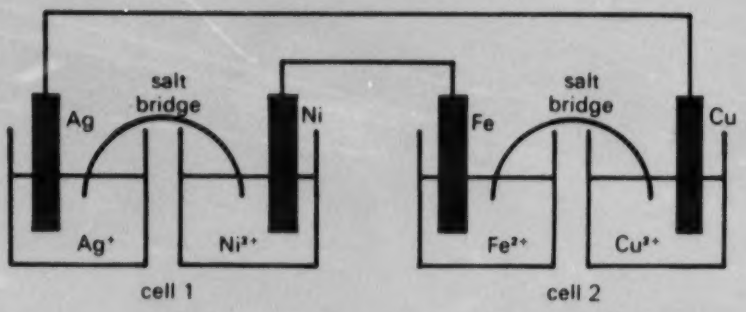
$[Ag^+] = [Ni^{2+}] = [Fe^{2+}] = [Cu^{2+}] = 1\ M$

$Ag^+ + e^- \rightarrow Ag \quad E^0 = +0.80\ V$

$Cu^{2+} + 2e^- \rightarrow Cu \quad E^0 = +0.34\ V$

$Ni^{2+} + 2e^- \rightarrow Ni \quad E^0 = -0.23\ V$

$Fe^{2+} + 2e^- \rightarrow Fe \quad E^0 = -0.41\ V$



Q3-5 30 **A** Which of the following statements **best** describes the processes occurring in the two cells?

A Cell 1 behaves as an electrochemical cell, and electrolysis occurs in cell 2.

B Cell 2 behaves as an electrochemical cell, and electrolysis occurs in cell 1.

C Both cells 1 and 2 behave as electrochemical cells.

D Electrolysis occurs in both cells 1 and 2.

E No reaction will occur in either cell.

Q3-6 40 **D** If a voltmeter is added to the circuit, the resultant potential of the two cells as connected in the diagram above is

A 1·03 V. **B** 0·75 V. **C** 1·78 V. **D** 0·28 V.

Q4 Ratios of products

Q4-1 40* **B** An electrochemical cell, cell 1, contains molten $CaCl_2$ and another cell, cell 2, contains molten NaCl. They are connected in series and a current is passed through them via platinum electrodes.

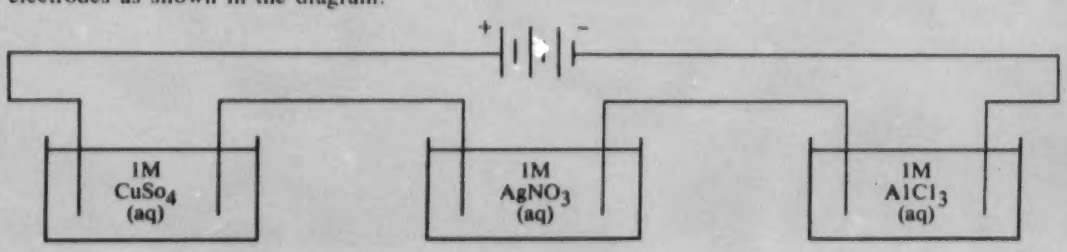
The molar ratio,

n(Ca) formed in cell 1: $n(Cl_2)$ formed in cell 1: n(Na) formed in cell 2,

is equal to

A 1:1:1. **B** 1:1:2. **C** 1:2:2. **D** 2:1:1. **E** 2:2:1.

Q4-2 10 **D** A steady current is passed for a fixed time through three cells containing aqueous solutions and platinum electrodes as shown in the diagram.



The molar ratio n(Cu) : n(Ag) : n(Al) of metal deposited at the negative electrode in each cell is

A 2 : 1 : 0. **B** 2 : 1 : 3. **C** 2 : 3 : 1. **D** 1 : 2 : 0.

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Q4-3
30
C

The following half-equations represent the production of magnesium and aluminium by the electrolysis of molten compounds:

(i) $Mg^{2+} + 2e^- \rightarrow Mg$
(ii) $Al^{3+} + 3e^- \rightarrow Al$

For the **same** quantity of electricity, the **simplest** ratio of the **mass** of magnesium deposited to the mass of aluminium deposited is (given A_r : Mg = 24, Al = 27)

A 3 to 3. **B** 3 to 2. **C** 4 to 3. **D** 8 to 9.

The next two items refer to the following information

The table below shows the formulae of the ions of four different metals and the relative atomic masses of these metals.

Ion in solution	Relative atomic mass
W^+	65
X^{2+}	210
Y^{3+}	140
Z^{4+}	120

In an experiment, a fixed amount of electricity was passed between inert electrodes dipping into solutions of each of these metal ions. Metal was deposited on the negative electrode in each solution.

Q4-4
60
A

The greatest number of metal **atoms** deposited from solution would be of metal

A *W*. **B** *X*. **C** *Y*. **D** *Z*.

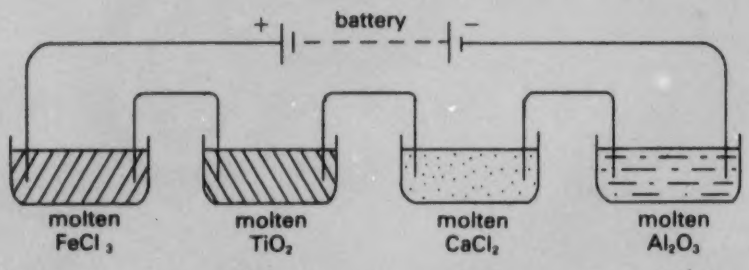
Q4-5
60
B

The greatest **mass** of metal obtained would consist of metal

A *W*. **B** *X*. **C** *Y*. **D** *Z*.

Q4-6
30
C

Electrolysis cells with inert electrodes were arranged in series as shown. The cells contained molten $FeCl_3$, TiO_2, $CaCl_2$ and Al_2O_3.



If a current were passed through the cells for a short time, which compound would produce the greatest mass of metal (given A_r: Ti = 47.9, Fe = 55.8, Ca = 40.1, Al = 27.0)?

A $FeCl_3$ **B** TiO_2 **C** $CaCl_2$ **D** Al_2O_3

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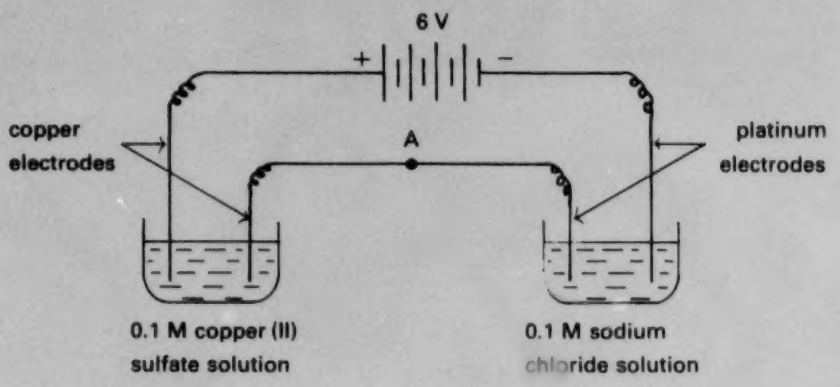
The next two items refer to the following information

Two electrolysis cells, one containing 0.1 M copper(II) sulfate solution and the other containing 0.1 M sodium chloride solution, were connected in series using wires as shown:



Q4-7 40 **D**

At point A in the connecting wire

A ions would move towards the platinum electrode.
B electrons would move towards the platinum electrode.
C ions would move towards the copper electrode.
D electrons would move towards the copper electrode.

Q4-8 40 **B**

After passing a current for some time, 2.24 dm^3 of hydrogen gas, measured at STP, was evolved at one of the electrodes. Which of the following would be formed at another electrode (given A_r Cu = 63.5, molar volume of a gas at STP = 22.4 $dm^3\ mol^{-1}$)?

A 2.24 dm^3 Cl_2
B 6.35 g Cu
C 2.24 dm^3 O_2
D 0.20 mol Cu^{2+}

Q5 Calculations using the Faraday constant

Q5-1 40 **D**

During the electrolysis of a molten ionic compound, the passage of 1.93×10^3 coulomb produced 1.51 g of element X (A_r = 150) at the cathode. If the total charge associated with one mole of electrons is 9.65×10^4 coulomb, an ion of X may be represented by

A X^{2-}. **B** X^-. **C** X^+. **D** X^{2+}. **E** X^{4+}.

Q5-2 70 **A**

The numerical value of the Faraday constant (F) is given as 96487.
This value represents

A the number of coulomb carried by 1 mol of charge.
B the number of electrons corresponding to 1 coulomb of charge.
C the number of electrons corresponding to 1 mol of electric charge.
D the number of ions discharged by the passage of 1 mol of electrons.

Q5-3 30 **D**

Electrolysis of 1 dm^3 of a 1.0 M nickel(II) sulfate solution using steel electrodes results in nickel being plated on the cathode. The concentration of nickel(II) ions in the solution after the passage of 0.2 faraday of charge is about

A 0.1 M. **B** 0.2 M. **C** 0.8 M. **D** 0.9 M.

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Q5-4 80 **C**

What current would be required to completely decompose 10 g of molten NaCl (M_r = 58.5) in 2.0 minutes (given F = 96487 C mol^{-1})?

A $\frac{10 \times 96487}{58.5 \times 2.0}$ A

B $\frac{10 \times 96487 \times 2.0 \times 60}{58.5}$ A

C $\frac{10 \times 96487}{58.5 \times 2.0 \times 60}$ A

D $\frac{58.5 \times 96487}{10 \times 2.0 \times 60}$ A

The next two items refer to the following information

Aluminium (A_r = 27.0) is manufactured by the electrolysis of Al_2O_3 dissolved in molten cryolite.

The reactions at the electrodes are: $Al_2O_3 + 6e^- \rightarrow 2Al + 3O^{2-}$

$C + 2O^{2-} \rightarrow CO_2 + 4e^-$

It can be assumed that no other reactions occur.

Q5-5 60 **D**

What volume of CO_2 gas is produced at STP during the manufacture of 1.0 kg of metal?

(Molar volume of CO_2 at STP = 22.4 dm^3 mol^{-1})

A $\frac{4 \times 1.0 \times 10^3 \times 22.4}{3 \times 27.0}$ dm^3

B $\frac{1.0 \times 10^3 \times 22.4}{27.0}$ dm^3

C $\frac{3 \times 27.0}{4 \times 1.0 \times 10^3 \times 22.4}$ dm^3

D $\frac{3 \times 1.0 \times 10^3 \times 22.4}{4 \times 27.0}$ dm^3

Q5-6 50 **A**

The time required for a cell operating at a current of 13000 A to produce 1.0 kg of metal is (given F = 96487 C mol^{-1})

A $\frac{3 \times 1.0 \times 10^3 \times 96487}{27.0 \times 13000}$ s.

B $\frac{3 \times 1.0 \times 10^3}{27.0 \times 96487 \times 13000}$ s.

C $\frac{1.0 \times 10^3 \times 96487}{27.0 \times 13000}$ s.

D $\frac{1.0 \times 10^3 \times 96487}{3 \times 27.0 \times 13000}$ s.

Q5-7 60 **D**

In the electrolytic manufacture of tin plate, a solution of $K_2Sn(OH)_6$ is used as the electrolyte. The mass of tin that would be deposited after electrolysis for 1 hour with a current of 0·3 A would be (given F = 96487C mol^{-1}; A_rSn = 118·69)

A $\frac{0{\cdot}3 \times 118{\cdot}69}{96487 \times 2}$ g.

B $\frac{0{\cdot}3 \times 60 \times 118{\cdot}69}{96487 \times 2}$ g.

C $\frac{0{\cdot}3 \times 60 \times 60 \times 118{\cdot}69}{96487 \times 2}$ g.

D $\frac{0{\cdot}3 \times 60 \times 60 \times 118{\cdot}69}{96487 \times 4}$ g.

E $\frac{0{\cdot}3 \times 60 \times 96487}{2 \times 118{\cdot}69}$ g.

F $\frac{0{\cdot}3 \times 60 \times 60 \times 96487}{4 \times 118{\cdot}69}$ g.

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Q6 Avogadro's constant from electrolysis data

Q6-1
50
A

A student wishes to determine the Avogadro constant by electrolysing a solution of copper sulfate.

Which one of the following quantities is *not* needed for his determination?

A the concentration of the copper sulfate solution
B the mass of copper deposited
C the amount of electricity in coulomb, passed through the electrolyte
D the value, in coulomb, of one elementary charge

Q6-2
60
A

0.120 g of copper (A_r = 63.5) was deposited when a current of 0.60 A was passed through a copper(II) sulfate solution for 608 seconds. Since the charge on an electron is 1.6×10^{-19} C, the value of Avogadro's constant is

A $\dfrac{0.60 \times 608 \times 63.5}{1.6 \times 10^{-19} \times 2 \times 0.120}$.

B $\dfrac{0.60 \times 608 \times 2 \times 2 \times 63.5}{1.6 \times 10^{-19} \times 0.120}$.

C $\dfrac{2 \times 0.120}{63.5 \times 0.60 \times 608 \times 1.6 \times 10^{-19}}$.

D $\dfrac{0.60 \times 608 \times 63.5}{1.6 \times 10^{-19} \times 0.120}$.

E $\dfrac{0.60 \times 608 \times 63.5 \times 1.6 \times 10^{-19}}{2 \times 0.120}$.

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R MEASUREMENT AND CHEMICAL TECHNIQUES

R1 Measurement

R1a Standard form

R1a-1 30 **A**

The amount of NaCl in 0·003 dm^3 of a 0·0200 M NaCl solution is best expressed in standard form as

A 6×10^{-5} mol.
B $6{\cdot}0 \times 10^{-5}$ mol.
C $6{\cdot}00 \times 10^{-5}$ mol.
D $6{\cdot}000 \times 10^{-5}$ mol.
E $6{\cdot}0000 \times 10^{-5}$ mol.

R1b Significant figures

R1b-1 20* **C**

A solution of volume 2·0 dm^3 contains 0·426 mol of Na_2CO_3. The concentration of the sodium carbonate is best expressed as

A 0·2130 M. **B** 0·213 M. **C** 0·21 M. **D** 0·2 M.

R1c Uncertainty

R1c-1 10* **D**

The uncertainty in each reading of a particular burette scale is quoted as $\pm$ 0·02 cm^3. The percentage uncertainty in a volume of 40·00 cm^3 delivered by the burette is

A 0·0005. **B** 0·001. **C** 0·05. **D** 0·1.

R1c-2 80 **C**

If (20 $\pm$ 2) cm^3 of water were removed from a flask containing (100 $\pm$ 10) cm^3 of water, the volume of liquid remaining would be

A (80 $\pm$ 8) cm^3.
B (80 $\pm$ 10) cm^3.
C (80 $\pm$ 12) cm^3.
D (80 $\pm$ 16) cm^3.

R1c-3 80 **D**

A flask of concentrated sodium hydroxide solution has a mass of (100·0 $\pm$ 0·4) g. After carbon dioxide gas was bubbled through the solution the mass of the flask was (160·0 $\pm$ 0·4) g.

The mass of carbon dioxide absorbed by the solution is best stated as

A (60·0 $\pm$ 0·0) g.
B (60·0 $\pm$ 0·1) g.
C (60·0 $\pm$ 0·4) g.
D (60·0 $\pm$ 0·8) g.

R1c-4 40 **C**

The amount of NaOH in (50·0 $\pm$ 0·2) cm^3 of a solution of concentration (1·000 $\pm$ 0·002) M is

A (0·050 $\pm$ 0·202) mol.
B (0·0500 $\pm$ 0·0001) mol.
C (0·0500 $\pm$ 0·0003) mol.
D (0·0500 $\pm$ 0·0006) mol.

R1c-5 40 **A**

(500 $\pm$ 5) cm^3 of a solution contains (50 $\pm$ 2) g of sodium chloride.

The uncertainty in the concentration of the solution, in g cm^{-3}, is

A $\pm$ 0·005. **B** $\pm$ 0·1. **C** $\pm$ 5. **D** $\pm$ 7.

R1c-6 50 **B**

The uncertainty in the volume of a 250 cm^3 standard flask is approximately

A 2·5 cm^3. **B** 0·25 cm^3. **C** 0·025 cm^3. **D** 0·010 cm^3.

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R1c-7 70 **D**

The volume delivered by a 20 cm³ standard pipette is approximately

A 20 ± 1 cm³.
B $20{\cdot}0 \pm 0{\cdot}1$ cm³.
C $20{\cdot}0 \pm 0{\cdot}2$ cm³.
D $20{\cdot}00 \pm 0{\cdot}01$ cm³.

R1d Random and systematic errors

R1d-1 80 **D**

A characteristic of random errors is that

A they are caused by incorrect calibration of apparatus.
B they are caused by permanent faults in apparatus.
C the error is the same for any measurement taken at random.
D their effect is reduced by calculating the mean of several measurements.

R1d-2 90 **C**

Two students attempted to determine the mass of water delivered by a pipette. Both students performed the determination four times. Their results, in gram, are listed below.

Student A: 24·96, 25·01, 25·10, 24·92.

Student B: 25·30, 25·32, 25·31, 25·34.

If the pipette actually delivers 25·00 g of water, which of the following statements is correct?

A Student A's results suggest systematic errors were present and have a higher precision.
B Student A's results suggest random errors were present and have a higher precision.
C Student B's results suggest systematic errors were present and have a higher precision.
D Student B's results suggest random errors were present and have a lower precision.

R1d-3 80 **C**

Four students (W, X, Y and Z) were asked to determine the mass of a watch glass. Each student weighed the watch glass four times.

Their results are given below.

Student	Mass of watch glass /g			
W	18·8	18·6	19·2	18·8
X	20·1	18·9	18·5	18·0
Y	19·3	19·5	19·4	19·5
Z	17·7	19·1	18·8	19·2

The mass of the watch glass was $(18{\cdot}90 \pm 0{\cdot}01)$ g.

Which student's results show evidence of a systematic error?

A W **B** X **C** Y **D** Z

R1d-4 70 **D**

An exercise in volumetric analysis requires the use of a balance, a pipette, a burette and a standard flask. A possible source of *systematic* as opposed to *random* error in the volumetric exercises would be

A careless reading of the liquid levels in the burette.
B carrying out weighings with the balance pan exposed to a draught of air.
C patches of grease on the inside of the pipette.
D incorrect labelling of the volume of the standard flask.

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R1d-5
40*
C

An exercise in volumetric analysis requires the use of a balance, a pipette, a burette and a standard flask. A possible source of *random* as opposed to *systematic* error in the volumetric exercise would be

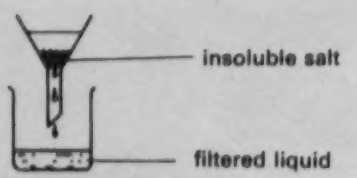
A a fault in the balance so that it always read 50 mg too light.
B incorrect labelling of the volume of the pipette.
C a leaky burette tap.
D allowing the pipette to drain for only 5 s instead of the recommended draining time of 30 s, following delivery of a volume of solution.

R2 Purification techniques

R2a Filtration

R2a-1
40
B

The diagram below represents an insoluble salt being separated from a liquid by filtration.



The solid collected by the filter paper is called the

A filtrate.
B residue.
C solute.
D precipitate.

R2a-2
60*
D

A filtrate is best described as the

A solution about to be filtered.
B solid material collected by a filter.
C solute present in a filtered solution.
D solution that has passed through a filter.

R2a-3
90
B

When a solution of sodium hydroxide is added to a solution of cobalt chloride, insoluble purple cobalt hydroxide and soluble sodium chloride are formed. Of the following methods, the cobalt hydroxide could best be separated from the sodium chloride by

A evaporation.
B filtration.
C paper chromatography.
D fractional distillation.

R2b Use of a separating funnel

R2b-1
30
A

A refinery worker added petrol to a storage tank without knowing that some salt water was already present in the tank. A sample of the mixture was withdrawn and taken back to the plant laboratory for study.

Which of the following procedures would best enable separation of the petrol and salt water mixture?

A separation using a separating funnel
B fractional distillation
C simple distillation
D filtration
E crystallization

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R2c-1 90 C

Crude petroleum contains a wide range of hydrocarbons which vary in size and structure. In order to separate the constituents of a sample of crude petroleum, which of the following techniques would be best?

A filtration
B simple distillation
C fractional distillation
D separation using a separating funnel

R2c-2 80 B

The following data refer to the two substances, methyl ethanoate and ethyl ethanoate

Compound	Formula	Melting Point /°C	Boiling point /°C	Density /g cm^{-3}	Solubility in water
methyl ethanoate	$C_3H_6O_2$	−98	57.5	0.93	miscible
ethyl ethanoate	$C_4H_8O_2$	−84	77	0.90	miscible

A student wished to separate a mixture of methyl ethanoate and ethyl ethanoate which are miscible with one another. The easiest method of separating the two would be by

A placing the mixture in a separating funnel, allowing the denser liquid to settle to the bottom, and collecting this liquid from the funnel in the normal way.
B performing a fractional distillation, and collecting two liquids in different vessels.
C freezing the mixture, then allowing this solid to sublime – the more volatile substance would be collected first.
D adding the mixture to water and allowing the more soluble compound to dissolve. The other compound could then be removed by filtration.

R2c-3 60* B

The most effective method of recovering the liquid ammonia from a solution of the salt sodium amide in liquid ammonia would be

A decantation.
B distillation.
C evaporation.
D filtration.

R2c-4 40 A

Which one of the following processes would be the most suitable for obtaining water from a solution of sugar in water?

A distillation
B evaporation
C filtration
D decantation

R2c-5 60* D

At one point in a distillation column containing a mixture of *X* and *Y*, the percentage of *X* in the vapour is 30 per cent and of *Y* in the liquid is 85 per cent. From this information we can conclude

A that there was more *X* than *Y* in the mixture fed into the column.
B that there was more *Y* than *X* in the mixture fed into the column.
C that there was about the same percentage of *X* and *Y* in the mixture fed into the column.
D very little if anything concerning the relative proportions of *X* and *Y* in the mixture fed into the column.

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5X

The next item refers to the following solubility data:

Solubility in 100 g of water

at 60 °C	NaCl	35 g	at 10 °C	NaCl	35 g
	$NaNO_3$	140 g		$NaNO_3$	80 g

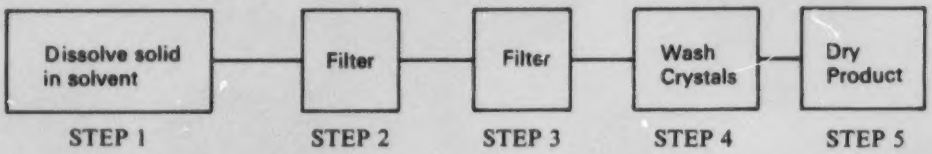
R2d-1 30 **B**

The following steps describe a procedure, based on these data, for obtaining some pure sodium nitrate from a sample of sodium nitrate which contains a small quantity of sodium chloride impurity. Which one of these steps is **not** essential?

A Step 1: Shake up the sample with sufficient hot water (about 65 °C) to form a concentrated solution.
B Step 2: Filter this solution.
C Step 3: Cool the solution.
D Step 4: Pour off the liquid.
E Step 5: Wash the crystals with distilled water.
F Step 6: Dry the crystals.

The next four items refer to the following information.

The steps in a typical recrystallization process can be summarized as follows:



R2d-2 80 **B**

In Step 1, the solid is dissolved in a

A minimum volume of solvent at room temperature.
B minimum volume of solvent at the solvent's boiling temperature.
C large volume of solvent at room temperature.
D large volume of solvent at the solvent's boiling temperature.

R2d-3 70 **D**

In Step 2, the solution is filtered at

A room temperature to remove insoluble impurities.
B elevated temperatures to collect crystals of product.
C room temperature to collect crystals of product.
D elevated temperatures to remove insoluble impurities.

R2d-4 80 **C**

In Step 3, the solution is filtered at

A room temperature to remove insoluble impurities.
B elevated temperatures to collect crystals of product.
C room temperature to collect crystals of product.
D elevated temperatures to remove insoluble impurities.

R2d-5 70 **B**

In Step 4, the crystals are **usually** washed with

A the filtrate from Step 3.
B pure solvent.
C a non-polar solvent.
D a polar solvent.

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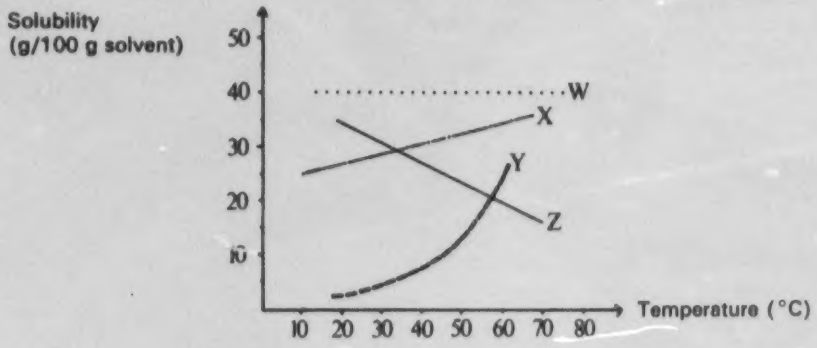
R2d-6
90
B

In the recrystallization process, the solute must be

A appreciably more soluble in the cold solvent than in the hot.
B appreciably more soluble in the hot solvent than in the cold.
C very soluble in both hot and cold solvent.
D insoluble in both hot and cold solvent.

R2d-7
90
C

The graph below shows the variation in the solubility of a compound in solvents W, X, Y and Z with temperature.



The best solvent to use in a recrystallization of the compound would be

A W. **B** X. **C** Y. **D** Z.

R2d-8
80
C

Which of the following is **not** a criterion for choosing a solvent for recrystallization?

A The solute should be relatively insoluble in the solvent at room temperature.
B The solvent should have a boiling temperature between 40 °C and 120 °C.
C The solute should be more soluble in the cold solvent than in the hot.
D The solvent and solute should be chemically compatible.

R2d-9
70
C

A chemist intends to purify a substance by recrystallization.

The substance has the following solubilities (in g dm^{-3}).

	Solubility at 25 °C	Solubility at boiling temperature of solvent
water	0·6	0·9
methanol	4·8	9·1
toluene	1·2	18·0
chloroform	30·0	50·0

The best solvent to use for recrystallization is

A water. **C** toluene.
B methanol. **D** chloroform.

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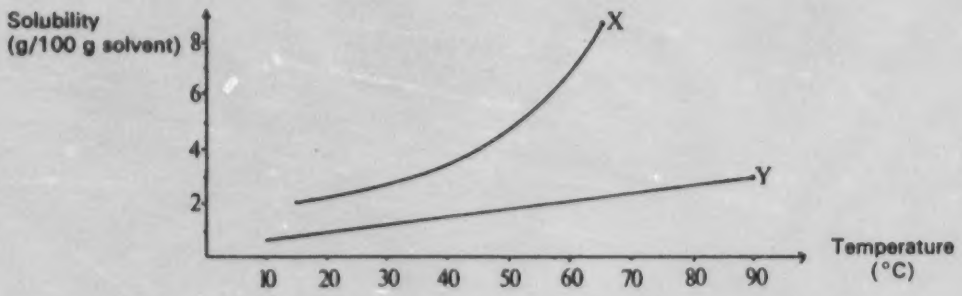
The next two items refer to the following information

The solubility curves for a substance in solvents X and Y are shown below. Solvent X boils at 70 °C and solvent Y boils at 90 °C.



R2d-10
80
E

The substance would be best recrystallized using solvent

A Y, because it dissolves less substance at all temperatures.
B Y, because its boiling temperature is higher.
C X, because its solubility curve is non-linear.
D X, because its boiling temperature is lower.
E X, because the solubility decreases rapidly with decreasing temperature.

R2d-11
30
A

A student elects to use solvent Y for a recrystallization. If 200 g of boiling solvent were required to completely dissolve the substance, what is the maximum mass of pure substance the student could obtain when the solution is cooled to 20 °C?

A 4 g B 3 g C 2 g D 1 g

R2d-12
40
C

A chemist wishes to choose a solvent for a recrystallization of an impure substance. Which of the following characteristics of the solvent would be the **least** desirable?

A The solubility of the desired product in the solvent increases rapidly with temperature.
B The impurities in the substance are very soluble in the solvent at high and low temperatures.
C The desired product is very soluble in the solvent at room temperature.
D The desired product is less soluble in the solvent than any impurities present.
E The desired product is more soluble in the solvent than any impurities present.

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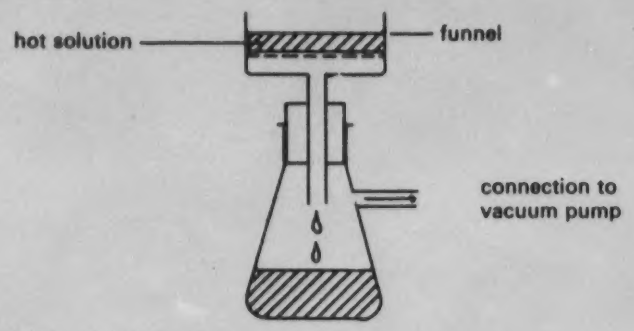
R2d-13
70
D

The hot solution prepared during a recrystallization is often filtered by vacuum filtration, using the apparatus shown below.



This filtration method is mainly used because

A the hot solvent evaporates more easily from the solute under reduced pressure.

B the solvent cools more rapidly under reduced pressure.

C oxygen is prevented from reacting with the hot solute.

D the solute is less likely to crystallize in the funnel.

R2e Miscellaneous purification items

The next three items refer to the following table:

Substance	Melting point /°C	Boiling point /°C	Solubility (in grams which will dissolve in 100 g of water at 20 °C)
octane	−57	126	both are miscible in each other at all concentrations, but insoluble in water
benzene	5.5	80	
sand	1700	higher than 1700	insoluble
iodine	sublimes	184	0.016
lead (II) iodide	300	—	0.068
iron(III) chloride	319	—	50

For each of the following mixtures select, from the following key, the separation technique which best satisfies both the criteria:

it is easy to perform in the laboratory; and
it gives the best yield of the substance underlined.

Key

I Dissolve in water, filter, and recrystallize from the filtrate by evaporation.

II Fractionally distil, and collect the distillate.

III Evaporate, allow the vapour to crystallize, and collect the crystals.

IV Filter, and collect either the filtrate or the residue.

V none of I, II, III and IV.

R2e-1
60
B

octane and benzene

A I **B** II **C** III **D** IV **E** V

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R2e-2 20* C

iodine and sand

A I B II C III D IV E V

R2e-3 60 A

iron(III) chloride and lead(II) iodide

A I B II C III D IV E V

The next four items refer to the following key

Key: **A** evaporation
B filtration
C distillation
D fractional distillation
E chromatography

Which one of these processes would be best employed to

R2e-4 90 D

separate kerosene from crude oil?

R2e-5 90 E

separate the dyes present in black ink?

R2e-6 80 B

separate a mixture of well ground sulfur and a copper sulfate solution?

R2e-7 90* A

increase the salinity of a large shallow pond of salt water?

R3 Quantitative and qualitative analysis

R3-1 70 A

Which **one or more** of the following would be classified as quantitative analysis?

A determination of the percentage of iron in a piece of sandstone
B determination of the presence of sodium in a sample of water
C separation of a mixture by thin layer chromatography
D identification of a liquid by absorption spectroscopy
E isolation of chlorophyll from leaves by column chromatography

R3-2 70 B

Flame tests may be used to determine if sodium is likely to be present in a chemical.

This procedure is an example of

A quantitative analysis.
B qualitative analysis.
C gravimetric analysis.
D atomic absorption spectroscopy.

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R4 Analysis techniques

R4a Chromatography

R4a-1 90* A

A universal indicator is made by dissolving methyl orange, bromothymol blue and phenolphthalein in alcohol.

Which of the following processes could best be used to separate the methyl orange component from the universal indicator solution?

A chromatography
B filtration
C distillation
D decantation

R4a-2 70 C

Which of the following measurements would be most useful in identifying an unknown component separated by a gas chromatograph?

A distance moved by the component through the stationary phase
B width of the component's peak on the recorder chart
C time taken for the component to pass through the instrument
D height of the component's peak on the recorder chart

R4a-3 50 C

Which of the following statements about the states of substances **within** a gas chromatograph is correct?

A The test sample only must be in the gaseous state.
B The mobile phase only must be in the gaseous state.
C The test sample and the mobile phase must be in the gaseous state.
D The test sample and the stationary phase must be in the gaseous state.
E The test sample, the mobile phase and the stationary phase must be in the gaseous state.

R4a-4 70 A

A petrol company finds that a rival product gives better test results in car engines. They suspect that the other company is adding methanol to its petrol, and request a chemist to test for this.

Which of the following analytical techniques would be the most suitable in this case?

A gas chromatography
B column chromatography
C paper chromatography
D thin layer chromatography
E atomic absorption spectroscopy

R4a-5 90 A

The most sensitive chromatographic technique is

A gas chromatography.
B column chromatography.
C paper chromatography.
D thin layer chromatography.

R4a-6 70 A

Which of the following substances could be used as the eluent in column chromatography?

A ethanol
B alumina
C nitrogen
D paper

R4a-7 60 B

When a solution containing substance X is placed on a chromatography column, the rate at which X moves down the column is different from that of the solvent.

The ratio of these rates is most directly related to the

A density of packing of the stationary phase.
B relative attractions of X and the solvent for the stationary phase.
C relative solubilities of X and the stationary phase in the solvent.
D rate of flow of the solvent through the chromatography column.

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R4a-8
90
B

A certain Asian herb is found to be an effective treatment for a serious illness. A drug company extracts the active chemical in impure form.

Which of the following techniques would be most suitable for obtaining the pure chemical in large amounts?

A gas chromatography
B column chromatography
C paper chromatography
D thin layer chromatography

R4a-9
90
C

Paper chromatography would be **most** suitable for

A detecting the presence of trace quantities of benzene in methylated spirits.
B extracting a large quantity of aspirin from tablets containing aspirin and phenacetin.
C separating the compounds present in a black dye.
D separating the clay particles from a sample of river water.

R4a-10
70
C

Which one of the following procedures is **least** likely to affect an analysis of a mixture using paper chromatography?

A leaving the paper in contact with the solvent for a very long period
B handling the paper before the chromatogram is run
C placing a pencil mark at the starting point of the mixture
D placing the paper in an open dish of solvent

R4a-11
80
B

Paper chromatography was used to separate the pigments in a plant leaf. A spot of the pigments was placed on a sheet of chromatography paper and the chromatograph was run inside a closed jar which was partly filled with ethanol.

The mobile phase in this instance is the

A pigments.
B ethanol.
C paper.
D ethanol vapour in the jar.

R4a-12
70
C

A chemist extracts a very small amount of colouring material from a rare flower. Which of the following analytical techniques would be most appropriate for determining whether the material is composed of a mixture of several pigments?

A gravimetric analysis
B column chromatography
C thin layer chromatography
D atomic absorption spectroscopy

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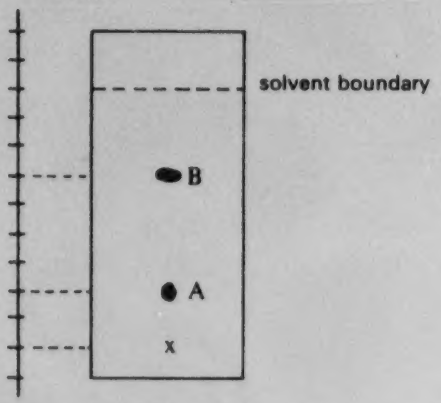
The next two items refer to the following information

The diagram below represents a thin layer chromatography plate which has been developed by standing the plate in a trough of solvent. Spots of a sample, containing components A and B, were originally placed at X.



R4a-13 70 **D**

Compared to component A, component B is absorbed

A more strongly onto the stationary phase, and has a larger R_f value.

B less strongly onto the stationary phase, and has a smaller R_f value.

C more strongly onto the stationary phase, and has a smaller R_f value.

D less strongly onto the stationary phase, and has a larger R_f value.

R4a-14 60 **A**

The value of R_f (B) is

A $\frac{2}{3}$. **B** $\frac{3}{2}$. **C** 3. **D** $\frac{1}{3}$. **E** $\frac{6}{10}$. **F** $\frac{10}{6}$.

The next five items refer to the following information

The table below lists some amino acids, together with their R_f values in two solvents.

Amino Acid	R_f Solvent 1	R_f Solvent 2	Amino Acid	R_f Solvent 1	R_f Solvent 2
alanine	0·24	0·55	lysine	0·12	0·55
2-aminobutyric acid	0·28	0·58	β-phenylamine	0·50	0·86
arginine	0·13	0·60	proline	0·39	0·88
glutamic acid	0·25	0·33	serine	0·19	0·34
glycine	0·20	0·40	taurine	0·12	0·33
hydroxyproline	0·21	0·67	threonine	0·21	0·49
isoleucine	0·57	0·81	tyrosine	0·38	0·62
leucine	0·58	0·82	valine	0·40	0·74

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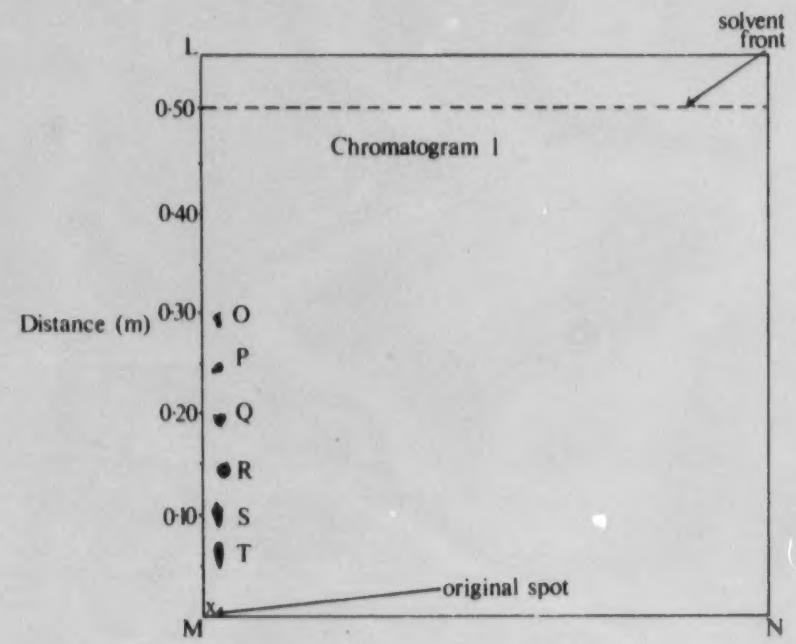
A small sample of a mixture of some of these amino acids is placed at the corner of a square piece of chromatography paper, and a chromatogram is developed using solvent 1. In the chromatogram below, L, M, N refer to the corners of the paper, O, P, Q, R, S and T to the spots on the chromatogram.



R4a-15 The R_f value for spot R using solvent 1 is approximately

80

B **A** 0·14. **B** 0·28. **C** 0·36. **D** 0·72.

R4a-16 The substance in spot O is

50

C

A 2-aminobutyric acid only.

B leucine only.

C isoleucine and/or leucine.

D some other combination of the amino acids listed in **A** to **C**.

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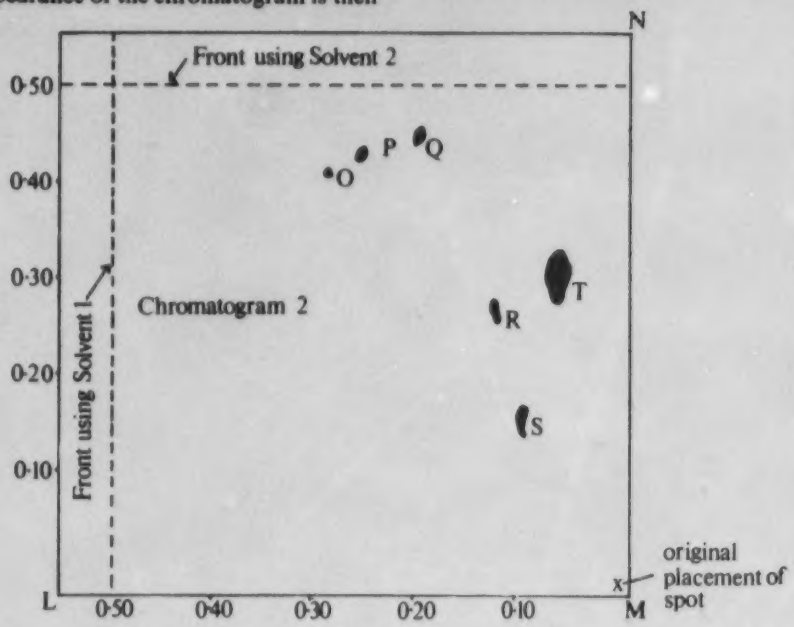
The chromatogram is now rotated so that the edge LM is in contact with solvent 2. The solvent is allowed to rise 0·50 m. The appearance of the chromatogram is then



R4a-17 80 **A**

The R_f value for spot O using solvent 2 is approximately

A 0·82. **B** 0·58. **C** 0·41. **D** 0·29.

R4a-18 20 **B**

The substance in spot P is

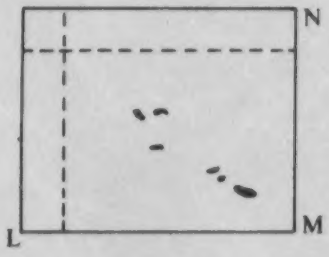
A proline only.
B β-phenylamine only.
C threonine only.
D proline and/or β-phenylamine.

R4a-19 70 **D**

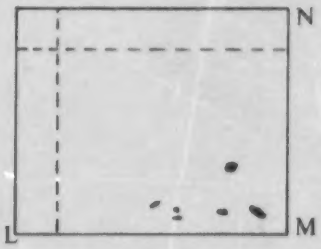
If a mistake had been made and solvent 1 was used instead of solvent 2 in the second stage, the chromatogram would be similar to

A Chromatogram 1 above.

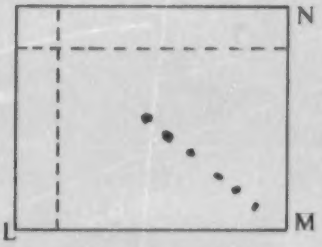
B



C



D



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R4b-1 50 C

The colour observed when a compound is heated in a Bunsen burner flame can give an indication of the

A number of elements in the compound.
B nature of the bonding in the compound.
C identity of cations in the compound.
D electronic configuration of atoms in the compound.

R4b-2 80 B

A sample of a substance is known to contain either potassium ions or sodium ions. The identity of the compound can be readily determined by observing the effect of

A adding a few crystals to acidified potassium permanganate solution.
B heating the substance in a Bunsen burner flame.
C adding litmus to a solution of the substance.
D adding a few crystals to a solution of sodium carbonate.

R4b-3 70* B

The following salts produce the flame colours listed.

Salt	*Observed flame colour*
lithium chloride	reddish-mauve
lithium nitrate	reddish-mauve
lithium carbonate	red to mauve

The best conclusion from these observations is that

A if a salt produces a reddish-mauve coloured flame, then that salt contains lithium ions.
B salts containing lithium ions produce a reddish-mauve flame colour.
C lithium ions are from an element which is coloured reddish-mauve.
D salts containing the Li^+ ion might be expected to be coloured.

R4b-4 40 C

The flame colours of three compounds are given below.

Compound	*Flame Colour*
NaCl	yellow
$CaCl_2$	brick-red
KCl	lilac

A sample of dustless chalk was crushed and a clean piece of nichrome wire dipped into it and then inserted in the hottest region of a Bunsen burner flame. Three students observed this test and described their observations as follows:

Student I: 'The flame was reddish.'
Student II: 'The flame was brownish-red and then became blue again.'
Student III: 'The flame became full red when the wire was inserted.'

On this evidence it may be concluded that the chalk probably contains a considerable proportion of

A chlorine.
B calcium chloride.
C calcium.
D potassium chloride and sodium chloride.

R4b-5 80 D

Which of the following metal ions could be incorporated in fireworks to produce yellow light?

A K^+ **B** Ca^{2+} **C** Ba^{2+} **D** Na^+

R4b-6 70* D

Which one of the following compounds does **not** produce a characteristic flame colour when heated in a non-luminous Bunsen flame?

A potassium nitrate
B barium chloride
C calcium chloride
D ammonium chloride

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R4b-7
40
B

A compound has the following chemical and physical properties:

I a gas is produced on treatment with dilute hydrochloric acid
II a non-luminous flame turns lilac if the compound is present

Of the following the compound could be

A $NaNO_3$. B K_2CO_3. C KNO_3. D Na_2CO_3.

R4c Melting temperature determination

R4c-1
40*
C

Measurements of the melting and boiling temperatures of a substance are used to indicate the

A elements present in the substance.
B strength of bonds within molecules.
C purity of the substance.
D heat of formation of the substance.

R4c-2
70*
C

A student has extracted aspirin powder from a number of commercial tablets and wishes to determine if his material is pure. Which one of the following measurements can be made most easily to give a reliable indication of the purity of the extract?

A density
B boiling point
C melting point
D solubility in alcohol

R4c-3
70
C

Compared with a pure substance, an impure sample of the substance melts

A at a higher temperature and over a wider temperature range.
B at a higher temperature and over a narrower temperature range.
C at a lower temperature and over a wider temperature range.
D at a lower temperature and over a narrower temperature range.

R4c-4
30
A

A sample of acetanilide contains a 5% benzanilide impurity. If the melting temperatures of the pure acetanilide were 114 °C and pure benzanilide were 163 °C, the melting temperature of the sample would be most likely to be

A less than 114 °C, over a temperature range of greater than 2°.
B greater than 114 °C, over a temperature range of greater than 2°.
C less than 114 °C, over a temperature range of less than 2°.
D greater than 114 °C, over a temperature range of less than 2°.

R4c-5
40
A

Maleic acid melts at 139 °C and malonic acid melts at 136 °C. A small amount of a substance, which is known to be either maleic acid or malonic acid, is mixed with a sample of malonic acid.

As the melting temperature of this mixture is increased, it would start to melt

A below 136 °C if the substance is maleic acid.
B between 136 °C and 139 °C if the substance is maleic acid.
C at 136 °C if the substance is maleic acid.
D at 139 °C if the substance is malonic acid.

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R4c-6
20
C

A chemist attempted to prepare four samples of urea using different synthetic methods. Three of the samples he prepared were mainly composed of urea, but the other sample he prepared was a different compound. The melting temperatures of the four samples (W, X, Y and Z) are given in the table below.

	W	X	Y	Z
melting range /°C	127–131	131–133	126–127	124–130

Which of the samples is probably **not** urea?

A W **B** X **C** Y **D** Z

R4c-7
70
A,C

A student is provided with four samples of chemicals labelled W, X, Y and Z. Each sample has a sharp melting temperature of 44 °C. The student finds that a mixture of X and Y melts between 35 °C and 40 °C, as does a mixture of Y and Z. However, a mixture of W, X and Z melts at 44 °C.

Which **one or more** of the samples X, Y, Z could be the same chemical as W?

A X **B** Y **C** Z

R4c-8
70
A

In a melting temperature determination of a sample of naphthalene, paraffin oil is used as the heating medium.

Which one of the following procedures should be adopted?

A pack the naphthalene firmly in the capillary tube
B raise the temperature rapidly
C avoid stirring the oil
D mix the naphthalene thoroughly with the oil

R4c-9
80
A

Which of the following procedures should **not** be followed during an accurate determination of melting temperature using a paraffin oil bath?

A The sample is packed loosely in a capillary tube.
B The oil is heated gently using a Bunsen burner.
C The sample is placed directly beside the bulb of a thermometer.
D The oil is stirred regularly using a metal ring.

R4d Gravimetric analysis

R4d-1
90
A

In order to perform a successful gravimetric analysis of the percentage of copper in a mass of copper ore, it should **not** be necessary to

A use an indicator to determine an equivalence point.
B weigh a sample of the ore accurately.
C dissolve the copper in the ore in a solvent.
D collect a precipitate by filtration.

R4d-2
70
D

Which one of the following pieces of apparatus **must** be used in an accurate gravimetric analysis?

A chromatographic column **C** burette **E** filter funnel
B volumetric flask **D** analytical balance

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R4d-3
80
B

Which of the following procedures is likely to be involved in the gravimetric analysis of iron in a steel sample?

A titration of Fe^{2+} ions in acid solution with a standard solution of $KMnO_4$
B measurement of the mass of Fe_2O_3 residue obtained by dehydration of a precipitate of $Fe(OH)_3$
C determination of the colour intensity of a solution of $FeSCN^{2+}$
D separation of Fe^{2+} ions from Fe^{3+} ions on a chromatography column using an acid as eluent

R4d-4
80
B,C

The moisture content of a wool consignment is obtained by measuring the mass of a sample of the wool, dehydrating by heating in an oven and then subsequently measuring the dried mass. The moisture content is then assessed by mass difference. This technique is an example of **one or more** of the following types of analysis.

Which one(s)?

A volumetric analysis
B quantitative analysis
C gravimetric analysis
D qualitative analysis

R4e Standard solutions, Primary standards

R4e-1
90
A

A standard solution is a solution which

A has an accurately known concentration.
B does not deteriorate or react with the atmosphere.
C is prepared using a volumetric flask.
D is prepared from an accurately measured mass of solute.

R4e-2
60
E

Which one of the following sets of apparatus is normally used in the preparation of a solution of a primary standard?

A analytical balance and pipette
B analytical balance and burette
C volumetric flask and pipette
D volumetric flask and burette
E volumetric flask and analytical balance

R4e-3
30
A,C

Sodium hydroxide pellets would not be suitable for use as a primary standard in the standardization of hydrochloric acid for **one or more** of the following reasons. Which one (s)?

A The pellets absorb moisture from the air.
B The endpoint for this titration is indistinct.
C The pellets react with carbon dioxide in the air.
D The pellets deteriorate in the presence of oxygen.
E The end point for this titration is not the same as the equivalence point.

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S CARBON CHEMISTRY

S1 The element

S1-1 70 **B**

Which **one** of the following displays a structure markedly different from the other four?

A diamond **B** graphite **C** silicon **D** silicon carbide **E** silica

S1-2 90 **D**

The addition of powdered graphite to a lock which has been sticking will often cause the key to turn more easily.

Graphite has this effect because

A each carbon atom has already formed four bonds, and hence can form an unreactive film over which metals can slide.

B its infinite lattice structure is very hard and strong, enabling moving parts to slide over a thin layer of graphite.

C the tetrahedral arrangement of bonds around each carbon atom causes neighbouring carbon atoms to slide past one another.

D the carbon atoms are bonded into two dimensional sheets which can slide freely over one another.

S1-3 50 **C**

The high electrical conductivity of graphite enables it to be used for brushes in electric motors.

Graphite conducts electricity because

A it has strong bonding in only two dimensions.

B it consists of sheets of atoms which can slide over each other.

C one electron pe atom is free to move in an electric field.

D it is composed of ions immersed in a mobile 'sea' of valence electrons.

S2 Hydrocarbons

S2a Composition

S2a-1 70 **B,C**

Which **one or more** of the following compounds is a hydrocarbon?

A glucose, $C_6H_{12}O_6$ **B** benzene, C_6H_6 **C** n-pentane, C_5H_{12} **D** methanol, CH_3OH

S2b Occurrence (oil, coal, natural gas)

S2b-1 50 **D**

Which one of the following is most abundant in crude oil?

A ethene, CH_2CH_2 **B** ethanol, CH_3CH_2OH **C** benzene, C_6H_6 **D** pentane, C_5H_{12}

S2b-2 80 **A**

The majority of the hydrocarbons found in oil have the general formula

A C_nH_{2n+2}. **B** C_nH_{2n+1}. **C** C_nH_{2n}. **D** C_nH_{2n-1}. **E** C_nH_{2n-2}.

S2b-3 30* **D**

Crude oil is **mainly** composed of

A hydrocarbons which have the general formula C_nH_{2n}.

B a mixture of hydrocarbons with relative molecular masses below 100.

C unsaturated hydrocarbons which boil over a wide temperature range.

D members of a homologous series of saturated hydrocarbons.

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S2b-4
90*
A

As the price of oil rises, many oil heating systems are being replaced by systems which burn natural gas. The major constituent of natural gas is

A methane. **B** ethane. **C** propane. **D** butane.

S2c Fractional distillation

S2c-1
70
B

Alkanes with relatively low molecular masses which are present in crude oil are usually separated in a process called

A reforming.
B fractional distillation.
C cracking.
D catalytic dehydrogenation.

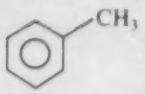
S2c-2
90
C

In the fractional distillation of crude oil,

A molecules are split into smaller molecules.
B alkanes are converted to alkenes.
C hydrocarbons are separated according to their boiling temperatures.
D aromatic hydrocarbons are produced from alkanes.

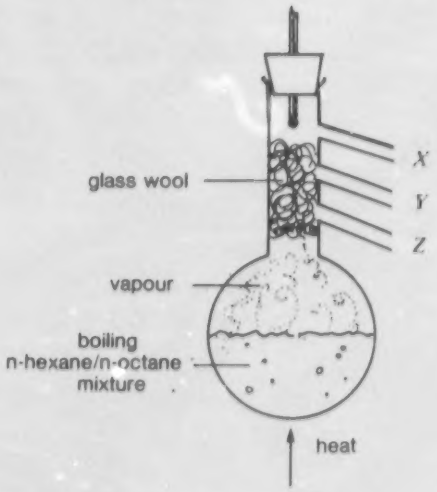
S2c-3
30
A

One of the first steps in the processing of petroleum is to pass it through a fractional distillation tower. Which of the following compounds is most likely to be obtained from an upper level of the fractionation tower?

A $CH_3CH_2CH_2CH_3$
B $CH_3(CH_2)_{16}CH_3$
C $CH_3CH{=}CH_2$
D 

S2c-4
60
C

A mixture of n-hexane (boiling point 69 °C) and n-octane (boiling point 126 °C) is heated in a fractional distillation apparatus, as shown in the diagram. Fractions are drawn off at the points labelled *X*, *Y*, and *Z*.



Compared with the fractions drawn off at *Y* and *Z*, the fraction drawn off at *X* is likely to have

A the highest boiling point and the highest proportion of n-hexane.
B the highest boiling point and the lowest proportion of n-hexane.
C the lowest boiling point and the highest proportion of n-hexane.
D the lowest boiling point and the lowest proportion of n-hexane.

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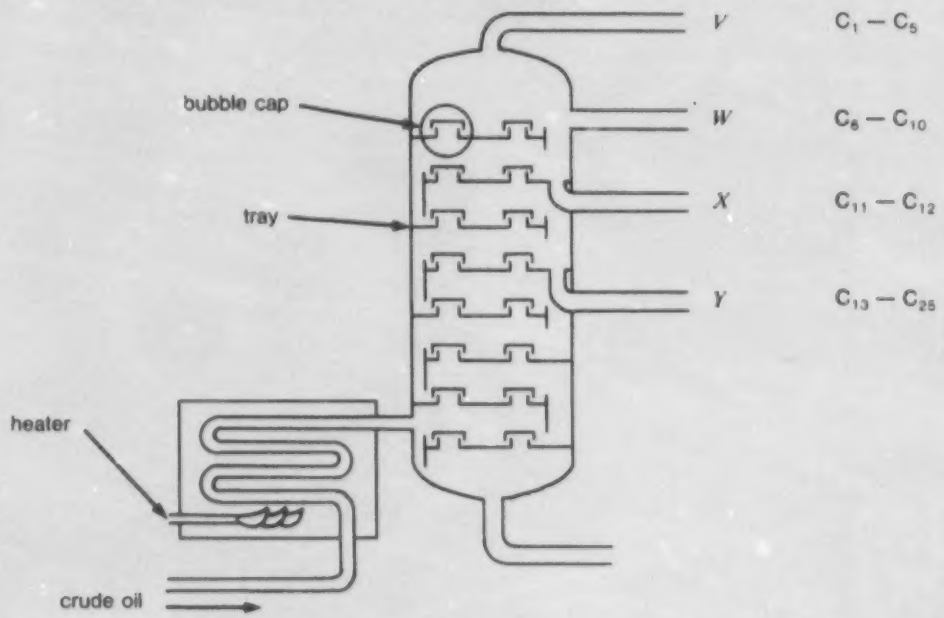
The next three items refer to the following information

The diagram below represents a fractionating tower which is used in the processing of crude oil. Hydrocarbon fractions are removed from outlets on the right hand side of the tower. The approximate numbers of carbon atoms in molecules from each fraction are indicated.



S2c-5 60 **B**

The fraction which is normally sold as petrol is

A *V*. **B** *W*. **C** *X*. **D** *Y*.

S2c-6 30 **D**

If the pressure within the tower were reduced substantially, the fraction obtained from *X* could contain hydrocarbons in the range

A C_6-C_{10}, because the boiling temperatures of the hydrocarbons would be increased.
B C_6-C_{10}, because the boiling temperatures of the hydrocarbons would be decreased.
C C_{13}-C_{25}, because the boiling temperatures of the hydrocarbons would be increased.
D C_{13}-C_{25}, because the boiling temperatures of the hydrocarbons would be decreased.
E C_{11}-C_{12}, because the boiling temperatures of the hydrocarbons would be unchanged.

S2c-7 60 **D**

Each tray in the fractionating tower contains a large number of bubble caps. The purpose of the bubble caps is to

A act as a catalytic surface for the decomposition of heavy fractions into lighter ones.
B prevent uncontrolled boiling caused by the passage of superheated steam through oil in the trays.
C separate the oil into fractions by passing it through sieves of various sizes.
D allow lower boiling fractions to rise higher in the tower than higher boiling fractions.

S2c-8 30 **C**

The heavy hydrocarbon fractions obtained from the fractional distillation of crude oil are often subjected to further distillation. The main reason for performing this process under vacuum is to

A prevent combustion of the hot liquids.
B 'crack' the heavy fractions into more volatile lighter fractions.
C allow the heavier fractions to boil without decomposing.
D distil hydrocarbons from the crude oil, leaving a residue of coke.

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S2d Cracking

S2d-1
90
A

The process of changing large hydrocarbon molecules to smaller molecules is called

A cracking.
B distillation.
C dehydrogenation.
D polymerization.

S2d-2
90
D

The term 'cracking' is used in the petroleum industry to refer to the

A addition of hydrogen to a compound.
B preparation of a polymer from a hydrocarbon monomer.
C formation of aromatic hydrocarbons from alkanes.
D conversion of long chain hydrocarbons to shorter chain varieties.

S2d-3
50
B

Crude oil contains a high proportion of hydrocarbons with a molecular mass of over 150, and yet most products of the petroleum industry have a molecular mass which is less than this.

The **formation** of these low relative molecular mass compounds is best achieved by

A heating the crude oil slowly, and collecting the various liquids as they evaporate.
B heating the crude oil, in the presence of a catalyst, to 500 °C for 10 minutes to shorten the average chain length.
C heating the crude oil, in the presence of a catalyst and hydrogen gas, to 140 °C, to saturate all double bonds present.
D burning the crude oil in an oxygen rich environment, and collecting and liquefying the evolved gases.

S2d-4
80
B

Over 50 % of Bass Strait crude oil consists of fractions with a relative molecular mass of 150 or more, yet 80 % of the crude oil is converted to petrol, which contains fractions with relative molecular masses of 120 or less.

This is achieved by

A vacuum distillation of the heavy hydrocarbon fractions.
B thermally or catalytically cracking the heavier hydrocarbon components.
C hydrogenation of the undesired fractions.
D catalytic reforming of the heavy hydrocarbon fractions.

S2d-5
70
C

Ethene (ethylene) may be obtained from crude oil by

A separating out the lighter components by fractional distillation.
B separating out the heavier components by fractional distillation.
C catalytic cracking of the crude oil followed by distillation.
D catalytic reforming of the crude oil followed by distillation.

S2d-6
40
C

The vapour above a candle which has just been extinguished contains hydrocarbons which are gases at room temperature.

The process leading to the formation of these compounds is best described as

A distillation.
B vaporization.
C cracking.
D reforming.

S2d-7
70
A

When a sample of crude oil is cracked its average boiling temperature

A is lowered.
B is raised.
C remains the same.

S2d-8
30
A

Which one of the following compounds would be **least** abundant in the products from the catalytic cracking of crude oil?

A benzene
B ethene (ethylene)
C hydrogen
D methane

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71

S3 Functional groups

S3-1 Which of the statements below best describes a functional group?

80

C

A It is the non-polar section in an organic molecule.

B It is a highly reactive group of elements with similar outer shell electron configurations.

C It is an atom or a group of atoms which determines the chemical properties of a compound.

D It is the part of a chelate ligand attracted to the central ion.

S4 Homologous series

S4-1 Which one of the following groups of formulae would represent members of a homologous series?

60

C

A CH_3Cl; CH_2Cl_2; $CHCl_3$; CCl_4

B CH_2CH_2; $CH_2CH_2CH_2$; $CH_2CH_2CH_2CH_2$; $CH_2CH_2CH_2CH_2CH_2$

C CH_4; CH_3CH_3; $CH_3CH_2CH_3$; $CH_3CH_2CH_2CH_3$

D CH_4; CH_3Cl; CH_3OH; $HCHO$

S4-2 A homologous series is a series of compounds in which the

80

A

A successive members differ by one carbon and two hydrogen atoms.

B successive members differ by a methyl (CH_3-) unit.

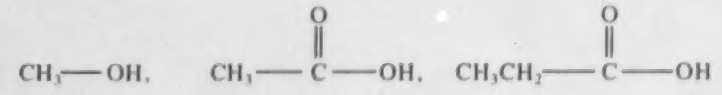
C compounds have the same molecular formula but different structural formulae.

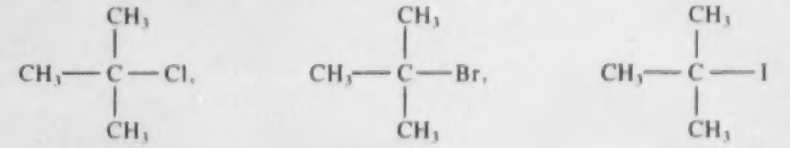
D compounds have different formulae but the same physical and chemical properties.

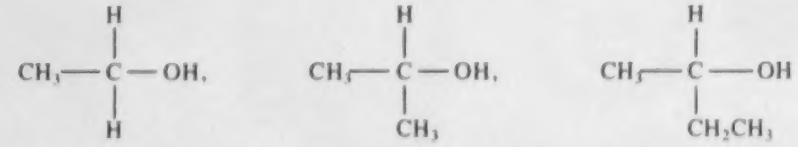
S4-3 Which one of the following groups of compounds represents a homologous series?

70

C

A 

B 

C 

D CH_3CH_2Cl, CH_3CHCl_2, CH_3CCl_3

S5 Isomerism

S5-1 Two organic compounds are structural isomers if they

90

A

A have the same molecular formula but different structural formulae.

B have the same structure in the solid state but different melting temperatures.

C differ from each other by a CH_2 unit.

D have the same physical properties but different molecular formulae.

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S5-2 60 C

The compounds $(CH_3)_2CHCHO$ and $CH_3CH_2CH_2CHO$ are

A isotopes.
B alcohols.
C isomers.
D ketones.

S5-3 80 C

Which one of the following statements concerning the compounds $CH_3CH_2CH_2CH_3$ and $(CH_3)_3CH$ is correct?

A They are members of different homologous series.
B They are saturated and unsaturated hydrocarbons.
C They are structural isomers.
D They have identical physical properties.

S5-4 40 C

One of the compounds below is an isomer of $CH_3OCH_2CH_3$.

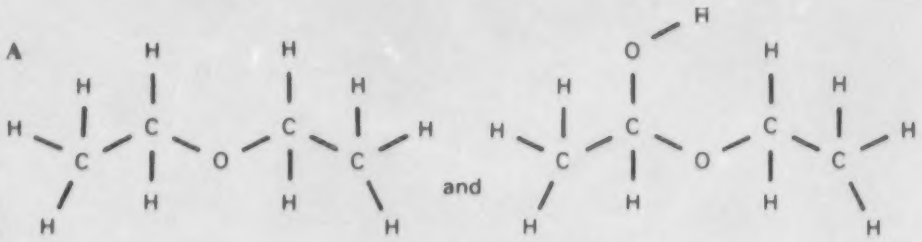
Which one?

A $CH_3CH_2OCH_3$
B $CH_3OCH_2CH_2CH_3$
C $CH_3CH_2CH_2OH$
D CH_3CH_2CHO

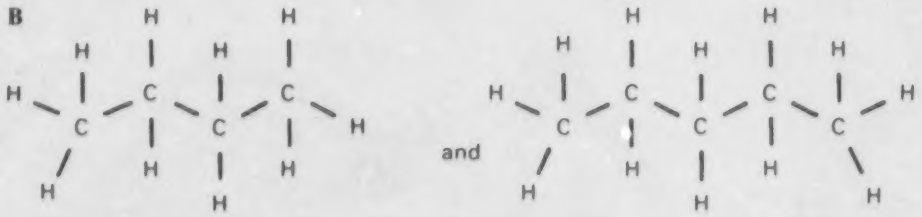
S5-5 70 C

Which of the following pairs of molecular structures represent isomers?

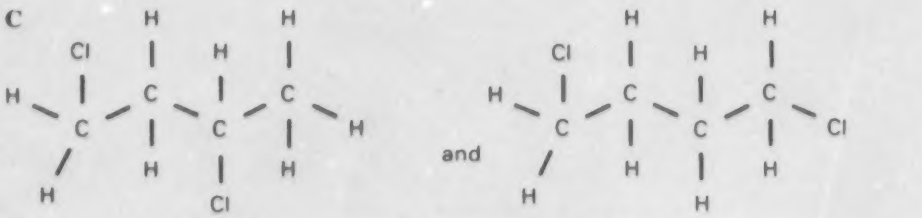
A



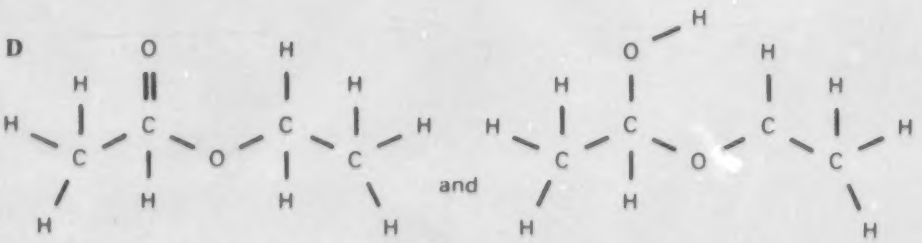
B



C



D



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S5-6 Which one of the following compounds does **not** exist in two or more structural forms?

70
C

A C_4H_{10} B C_3H_7Cl C C_2HCl_3 D $C_2H_4Cl_2$

S5-7 The number of structural isomers of chloropropane possible is

40
B

A 1. B 2. C 3. D 8.

S5-8 When normal butane is chlorinated, the number of dichloro isomers possible is

20
D

A 2. B 4. C 5. D 6.

S5-9 Which of the following compounds will have the greatest number of structural isomers?

30
B

A C_3H_8 B $C_3H_6Cl_2$ C C_4H_{10} D CH_3NH_2

S6 Alkanes

S6a Nature

S6a-1 A common feature of the alkanes is that they all have

70
C

A the same empirical formula. C similar chemical properties.
B the same molecular formula. D similar relative molecular masses.

S6a-2 The first three members of the homologous series of alkanes are

80
B

A methane, ethane, butane. C ethane, methane, propane.
B methane, ethane, propane. D ethane, butane, propane.

S6a-3 Which **one or more** of the following compounds are members of the same homologous series as ethane, CH_3CH_3?

30
B,C,D

A $CH_2=CH_2$ B $(CH_3)_3CH$ C CH_4 D $(CH_3)_2CH_2$

S6a-4 Which one of the following compounds is **not** an alkane?

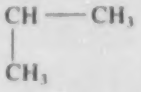
80
B

A CH_4 B CH_2CH_2 C $(CH_3)_3CH$ D $C_{30}H_{62}$

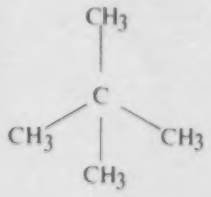
S6a-5 Which of the following structural formulae represents the fourth member of the homologous series of alkanes?

90
B

A $CH_3-CH_2-CH_3$

B 

C $H_2C=CH-CH=CH_2$

D 

S6a-6 A hydrocarbon was found to have a molecular formula of C_6H_{12}.

30*
C

To which of the following classes of compounds could this hydrocarbon belong?

A alkane C cyclic alkane
B cyclic alkene D aromatic hydrocarbon
E alkyne

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S6b Nomenclature

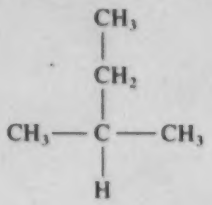
S6b-1 80 C

The formula of 2,2-dimethylpropane may be written as

A $(CH_3)_2CHCH_2CH_3$.
B $CH_3CH(CH_3)_2$.
C $(CH_3)_3CCH_3$.
D $(CH_3)_2CHCH_2CH(CH_3)_2$.

S6b-2 50 D

The hydrocarbon with the chemical formula



has the systematic name

A 1,1-dimethylpropane.
B 2-ethylpropane.
C 3-methylbutane.
D 2-methylbutane.

S6b-3 70 D

Which one of the following compounds has **not** been named correctly?

A 2,2-dimethylbutane
B 2-methylbutane
C 2-chloropropane
D 1-methylpropane

S6c Structure

S6c-1 40 A

The arrangement of the bonds around the carbon atoms in the molecule $(CH_3)_3CCH_2CH(CH_3)_2$ is

A tetrahedral.
B linear and tetrahedral.
C trigonal planar and tetrahedral.
D linear and trigonal planar.
E linear, trigonal planar and tetrahedral.

S6c-2 70 D

Which one of the following compounds is saturated?

A CH_2CH_2 B CH_3CHCH_2 C C_6H_6 D $(CH_3)_3CH$

S6c-3 60 B

The structure of solid methane could best be described as

A a layer lattice with weak bonding between the layers.
B a molecular solid with only weak dispersion forces between molecules.
C a network lattice with strong covalent bonding between adjacent molecules.
D a molecular lattice with hydrogen bonding and dispersion forces between molecules.

S6c-4 20* C

The most stable structure of cyclohexane at room temperature is one in which the carbon atoms are arranged in a

A plane.
B 'boat' shape.
C 'chair' shape.
D tetrahedron.

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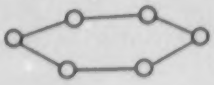
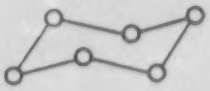
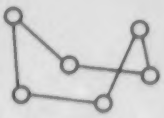
S6c-5 40* B

Cyclohexane is one of the hydrocarbons found in crude oil. Which of the diagrams below best represents the most stable arrangement of carbon atoms in a molecule of cyclohexane at room temperature?

A

C 

B 

D 

S6d Properties

S6d-1 70 D

Which of the following hydrocarbons is **least** likely to react with hydrogen?

A C_6H_6 B C_3H_6 C C_2H_2 D C_4H_{10}

S6d-2 80 C

The major hydrocarbon constituent of petrol is octane — C_8H_{18}. Of the following, the equation which correctly describes the complete combustion of octane in air is

A $2C_8H_{18} + 9O_2 \rightarrow 16C + 18H_2O$.
B $2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$.
C $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$.
D $2C_8H_{18} + 34O_2 \rightarrow 16CO_2 + 18H_2O_2$.

S6d-3 40 B

When a particular organic substance is burnt, the products are carbon dioxide and water only. This information enables us **to be certain** that the substance contains, apart from carbon,

A oxygen only.
B hydrogen only.
C hydrogen and oxygen only.
D hydrogen, oxygen and nitrogen only.

S6d-4 50 C

1 mol of an alkane requires 8 mol of oxygen for complete combustion. The molecular formula of the alkane is

A C_3H_8.
B C_4H_{10}.
C C_5H_{12}.
D C_6H_{14}.
E C_8H_{18}.

S6d-5 50 A

Carbon dioxide and water vapour are formed when methane burns in excess air. What mass of carbon dioxide is formed in a reaction in which 1 g of water vapour is produced (given M_r: $CO_2 = 44$, $H_2O = 18$)?

A $\frac{11}{9}$ g
B $\frac{22}{9}$ g
C $\frac{9}{11}$ g
D $\frac{9}{22}$ g

S6d-6 50 C

20 g of oxygen is required for complete combustion of a hydrocarbon. If 9 g of water is formed, the formula of the hydrocarbon is

(given A_r: O = 16, H = 1)

A C_2H_2. B C_2H_6. C C_3H_8. D C_4H_{10}.

S6d-7 90 D

The numbers of molecules of carbon dioxide and water formed when a particular hydrocarbon is completely burnt in air are in the ratio 1:2. The ratio of the atoms of carbon to hydrogen in the hydrocarbon is therefore

A 1:1. B 1:2. C 1:3. D 1:4.

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S6d-8 80 D

When a hydrocarbon was burned in excess air, the volumes of water vapour and carbon dioxide gas produced were in the ratio 2:1.

If the volumes of both gases were measured at the same temperature and pressure the hydrocarbon could be

A benzene.
B ethane.
C ethene (ethylene)
D methane.

S6d-9 30 A

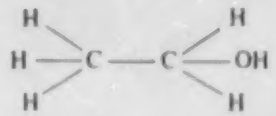
If equal masses of each of the following hydrocarbons were burnt in excess air, which one would produce the greatest mass of water vapour (given A_r: O = 16, C = 12, H = 1)?

A methane
B ethene (ethylene)
C ethane
D benzene

S6d-10 70 B

If the same number of molecules of each of the following substances were burnt completely in oxygen, which substance would yield the greatest mass of water?

A



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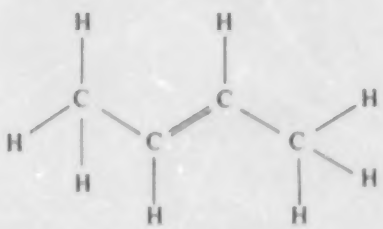

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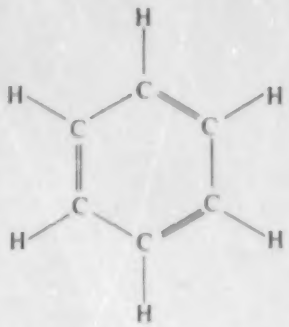

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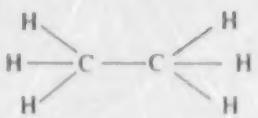

S6d-11 80 B

The reaction between chlorine and methane in ultraviolet light is an example of

A an elimination reaction.
B a substitution reaction.
C an addition reaction.
D a condensation reaction.

S6d-12 40 A

When 1 mol of methane, CH_4, and 1 mol of chlorine, Cl_2, are mixed and the mixture exposed to bright light, a reaction occurs. The chlorinated organic products of the reaction are

A CH_3Cl, CH_2Cl_2, $CHCl_3$ and CCl_4.
B CH_3Cl only.
C CCl_4 only.
D CH_2Cl_2 only.
E CH_3Cl and $CHCl_3$ only.

S6d-13 30 D

A mixture of ethane and chlorine reacts when exposed to bright sunlight. Which of the following statements concerning this reaction is **incorrect?**

A The reaction produces a mixture of products which can be separated by fractional distillation.
B The first step in the reaction mechanism is the dissociation of a chlorine molecule.
C Some of the hydrogen atoms in ethane are replaced by chlorine atoms during the reaction.
D The reaction ceases as soon as the mixture is shaded from the light.

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S6d-14
20*
E

The most abundant product from the reaction of 2 mol of chlorine with 1 mol of methane in ultraviolet light is likely to be

A CH_3Cl.
B CH_2Cl_2.
C $CHCl_3$.
D CCl_4.
E HCl.

S6d-15
40
C

The reaction between bromine and methane can be initiated by light. The function of the light is to

A produce high energy Br_2 molecules which attack the methane.
B break the C-H bonds in methane to produce reactive species.
C split the bromine molecules into atoms which attack the methane.
D raise the temperature of the mixture to increase the rate of reaction.

S7 Alkenes

S7a Nature

S7a-1
80
B

The petrochemical industry uses vast quantities of the alkenes which are produced by cracking petroleum.

Which one of the following compounds is an alkene?

A $(CH_3)_2CHCH_3$
B CH_3CHCH_2
C C_6H_6
D C_2H_2
E CH_3CH_2CHO

S7b Structure

S7b-1
40
A

In an ethene (ethylene) molecule the arrangement of atoms about a carbon atom is

A triangular planar.
B rectangular.
C tetrahedral.
D square planar.

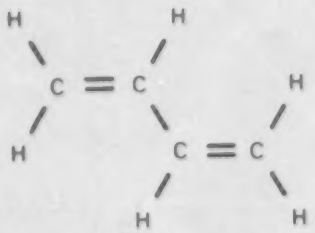
S7b-2
70
B

In which one of the following compounds is the arrangement of atoms around each carbon atom **not** tetrahedral?

A $(CH_3)_3CH$ B C_2H_4 C $CH_3CH_2CH_2CH_3$ D C_5H_{12}

S7b-3
80
D

Butadiene—structural formula



is a reactive chemical used extensively in the production of synthetic rubber.

It is often described as an 'unsaturated' hydrocarbon because

A butadiene molecules are unstable and react easily.
B each butadiene molecule has two fewer hydrogen atoms than each butane molecule.
C each carbon atom in butadiene has only three shared electron pairs instead of four.
D each molecule of butadiene contains double bonds.

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S7c Properties

S7c-1 40 **B**

1 mol of an organic compound, *X*, reacts completely with 2 mol of hydrogen gas in the presence of a nickel catalyst to form 1 mol of an alkane. Which one of the following compounds could *X* be?

A $CH_2=CH-CH=CH-CH=CH_2$

B $CH_2=CH-CH_2-CH_2-CH=CH_2$

C $CH_2=CH-CH_2-CH_2-CH_2-CH_3$

D

S7c-2 50 **D**

Which of the following compounds would react most readily with bromine at room temperature?

A benzene **B** ethanol **C** butane **D** ethene (ethylene)

S7c-3 30 **C**

The product formed when ethene (ethylene) reacts with bromine at room temperature is likely to be

A CH_3CH_2Br **B** CH_2CHBr **C** CH_2BrCH_2Br **D** CH_3CHBr_2

S7c-4 40 **B**

Naphthalene, $C_{10}H_8$, is an unsaturated hydrocarbon which undergoes a substitution reaction with Br_2. One of the most abundant products from this reaction would be

A H_2. **B** HBr. **C** $C_{10}H_8Br$. **D** $C_{10}H_8Br_2$.

S7c-5 70 **D**

Which of the following compounds is **least** likely to undergo addition reactions with chlorine?

A CH_2CH_2 **B** CH_3CHCH_2 **C** CH_2CHCl **D** $CH_3CH_2CH_3$

S7c-6 20 **A**

Chloroethane (ethyl chloride) is formed when ethene (ethylene) reacts with

A HCl gas.

B Cl_2 gas.

C Cl_2 gas in the presence of $FeCl_3$ powder.

D hydrochloric acid solution.

S7c-7 50 **B**

The reactants in four reactions involving hydrocarbons are shown below. In which case is an addition reaction likely to occur?

A $CH_4 \xrightarrow[\text{ultraviolet light}]{Cl_2}$

B $H_2CCH_2 \xrightarrow{HCl}$

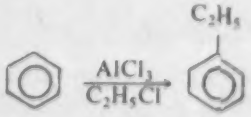
C $C_6H_6 \xrightarrow[H_2SO_4]{HNO_3}$

D $C_4H_{10} \xrightarrow[100\ ^\circ C]{O_2}$

S7c-8 80 **C**

Which of the reactions below is an addition reaction?

A $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$

B 

C $C_2H_4 + HCl \rightarrow C_2H_5Cl$

D $CH_3CH_2OH \xrightarrow[H^+]{Cr_2O_7^{2-}} CH_3COOH$

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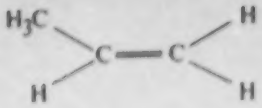
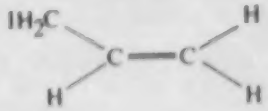
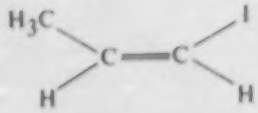
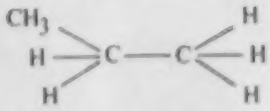
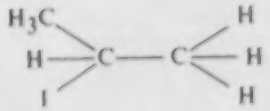
S7c-9
50
D

If propene,  , were bubbled through a solution of hydrogen iodide, HI, in an inert solvent at room temperature, the major product would be expected to be

A 

B 

C 

D 

S7c-10
80
D

Ethene (ethylene) reacts with water to produce ethanol according to the equation

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

This reaction is described as

A a condensation reaction.
B a substitution reaction.
C an acid-base reaction.
D an addition reaction.

S7c-11
50
C

Most of the world's supply of ethanol is produced from ethene (ethylene). This process is best classified as

A an elimination reaction.
B a substitution reaction.
C an addition reaction.
D a dehydration reaction.

S8 Alkynes

S8-1
70*
C

Which one of the following could be an alkyne?

A C_3H_8 B C_4H_8 C C_5H_8 D C_2H_5O

S8-2
80
D

Which one of the following best represents a general formula for an homologous series of alkynes?

A C_nH_{2n+1} B C_nH_{2n} C C_nH_{2n-1} D C_nH_{2n-2}

S9 Aromatic hydrocarbons

S9a Nature

S9a-1
40
B

The following substances are used extensively by man.

Which one may be classified as an aromatic compound?

A propene B aspirin C nylon D glycerol

S9a-2
60
C

The chemical structure

represents a molecule of empirical formula

A C_6H_3. B C_7H_3. C C_7H_8. D C_7H_9. E C_7H_{14}.

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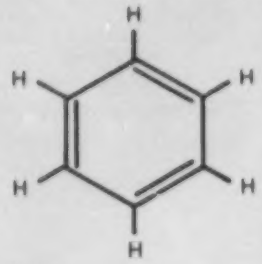
S9b Structure

S9b-1 60 C

For many years chemists used the following structure to represent the benzene molecule.



This structure is unsatisfactory because

A in some benzene molecules the double bonds are adjacent to one another.
B each benzene molecule actually has six equivalent double bonds.
C two electrons from each double bond are actually shared with the other four carbon atoms.
D the carbon atoms are arranged in a circle, and not in a hexagon, as this structure suggests.

S9b-2 80 D

The bonds between carbon atoms in benzene are

A single bonds.
B double bonds.
C alternate single and double bonds.
D intermediate between single and double bonds.

S9b-3 50 B

Which one of the following statements about the structure of benzene is **incorrect?**

A All carbon and hydrogen atoms lie in a plane.
B There are three short C=C double bonds and three longer C–C single bonds.
C The angle between the C–H bonds and neighbouring C–C bonds is 120°.
D All C–H bonds are of equal length.

S9b-4 40 A,B

Which **one or more** of the molecules below is (are) planar?

A C_2H_4 **B** C_6H_6 **C** C_3H_8 **D** CH_3NH_2

S9c Properties

S9c-1 70 A

Benzene is relatively unreactive. However a vast number of benzene derivatives are common and important compounds. The preparations of these compounds from benzene usually begin with a particular type of reaction. This type of reaction is

A a substitution reaction.
B an addition reaction.
C a polymerisation reaction.
D a condensation reaction.

S9c-2 70 D

Ethene (ethylene) and benzene are unsaturated hydrocarbons which are used in the preparation of a wide range of organic compounds. Which one of the following statements about the reactions of ethene and benzene is correct?

A Both compounds readily undergo addition reactions.
B Both compounds readily undergo substitution reactions.
C Benzene usually undergoes addition reactions whereas ethene usually undergoes substitution reactions.
D Benzene usually undergoes substitution reactions whereas ethene usually undergoes addition reactions.

S9c-3 50 D

250 cm^3 of gaseous benzene is to be completely hydrogenated to cyclohexane (C_6H_{12}).
If the volume of hydrogen required is measured under the same conditions of temperature and pressure, it will be

A 125 cm^3. **B** 250 cm^3. **C** 500 cm^3. **D** 750 cm^3.

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8i

S9c-4 70 C

A major product when benzene is treated with Cl_2 and $FeCl_3$ at room temperature in the absence of sunlight is likely to be

A $C_6H_6Cl_2$. B C_6H_6Cl. C C_6H_5Cl. D $C_6H_6Cl_6$.

S9c-5 30 C

Which of the following compounds will react most slowly at room temperature with chlorine in bright sunlight?

A ethene (ethylene) B methane C benzene D silane

S9c-6 50 B

Nitrobenzene is an important chemical in the manufacture of dyestuffs. It is best prepared by treating benzene with

A NO gas in the presence of platinum metal.
B a concentrated mixture of H_2SO_4 and HNO_3.
C NO_2 gas in the presence of $Al(NO_3)_3$ powder.
D a mixture of nitrogen and oxygen gas at 300 °C.

S9c-7 50 B

In the following conversions

1 methanol to dichloromethane
2 ethene (ethylene) to chloroethane
3 chlorobenzene to nitrobenzene

substitution reactions occur in cases

A 1 and 2 only. C 2 and 3 only.
B 1 and 3 only. D 1, 2 and 3.

S10 Halohydrocarbons

S10-1 70 B

Millions of aerosol spray cans are used annually to dispense a wide variety of products.

Which of the following compounds would be most useful as a propellant in aerosol cans?

A CCl_4 B CF_2Cl_2 C HCHO D $CHCl_3$

S10-2 70 A

Which one of the following compounds is likely to be used as a dry cleaning agent?

A CCl_2CCl_2 B CH_3CH_2OH C CH_3CONH_2 D CH_3CH_3

S10-3 30 B

Which of the following compounds is likely to be the **least** soluble in water?

A $CH_3CH_2CH_2NH_2$
B $CH_3CH_2CH_2Cl$
C $CH_3CHOHCH_3$
D $CH_3CH_2CONH_2$
E $CH_2OHCHOHCH_2OH$

S10-4 90 A

The reaction between 2-chlorobutane and an aqueous solution of sodium hydroxide results in the formation of

A an alcohol. C a carboxylic acid.
B an ester. D a ketone.

S10-5 60 A

Compound *X* is insoluble in water. When this compound is reacted with potassium hydroxide solution, one of the products is propanol.

Of the following, compound *X* would be

A bromopropane. C propanoic acid.
B ethyl propanoate. D propanal.

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S10-6 60 **D**

Alcohols are used extensively as industrial solvents or as the starting material for the manufacture of other chemicals. Alcohols may be conveniently prepared in the laboratory by the reaction between

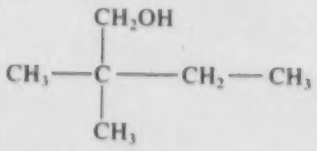
A a carboxylic acid and acidified potassium dichromate.
B an alkane and sodium hydroxide solution.
C an aldehyde and an oxidant.
D a chloroalkane and hydroxide ions.

S11 Alcohols

S11a Nature

S11a-1 50 **B**

The compound

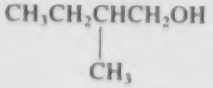


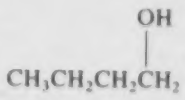
is best classified as

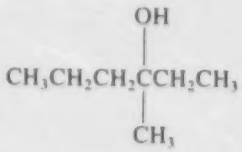
A an aldehyde.
B a primary alcohol.
C a secondary alcohol.
D a tertiary alcohol.

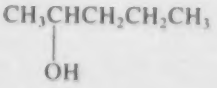
S11a-2 90 **D**

Which one of the following alcohols is a **secondary** alcohol?

A 

B 

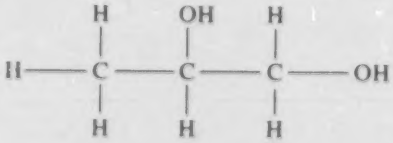
C 

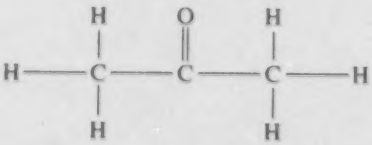
D 

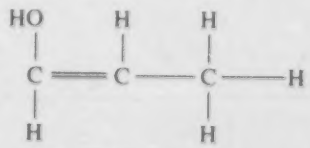
S11a-3 60 **D**

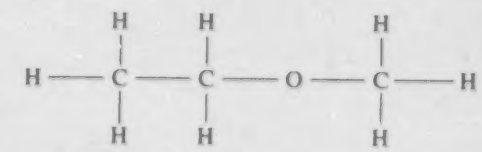
One of the following compounds is a structural isomer of 2-propanol.

Which one?

A 

B 

C 

D 

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S11b-1 20 **D**

Which one of the following compounds would boil at the highest temperature?

A $CH_3CH_2CH_2CHO$

B $CH_3CH_2\overset{\overset{O}{\|}}{C}CH_3$

C $CH_3CH_2CH_2CH_2CH_3$

D $CH_3CH_2CH_2CH_2OH$

S11b-2 20 **A**

The evaporation of water from dams is a serious problem in many areas of Australia. The rate of evaporation can be reduced by adding chemicals which float on the surface of the water.

Which one of the following chemicals would be most useful for this purpose?

A $CH_3(CH_2)_{14}CH_2OH$

B $CH_3(CH_2)_2CH_3$

C $CH_2OHCHOHCH_2OH$

D CH_3COOH

S11b-3 60 **B**

When sodium metal is added to a colourless liquid obtained during the destructive distillation of wood chips, a vigorous reaction occurs and a gas is evolved.

The liquid could be

A CH_3CHO.

B CH_3OH.

C CH_3COOCH_3.

D CH_3COCH_3.

S11b-4 60 **C**

The formation of an aldehyde from an alcohol is an example of a class of reaction called

A addition.

B substitution.

C redox.

D condensation.

S11b-5 90 **C**

The oxidation of alcohols in an acidified aqueous solution of potassium dichromate occurs easily for

A primary alcohols only.

B tertiary alcohols only.

C primary and secondary alcohols only.

D secondary and tertiary alcohols only.

E primary, secondary and tertiary alcohols.

S11b-6 60 **B**

A compound *X* of formula C_3H_8O is oxidized by a mixture of potassium dichromate and concentrated sulfuric acid to a compound of formula C_3H_6O.

From this information *X* is most likely to be

A an aldehyde.

B an alcohol.

C a ketone.

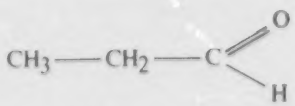
D a carboxylic acid.

E an ester.

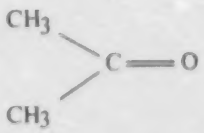
S11b-7 70 **D**

A major product of the reaction of CH_3CH_2OH with acidified potassium dichromate solution is likely to be

A



B



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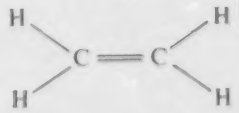

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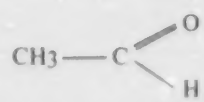

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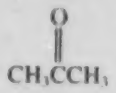
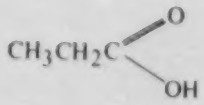
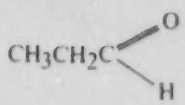
S11b-8 Which of the following compounds is **least** likely to be an oxidation product of 1-propanol?

40

A

A 

B 

C 

D CO_2

S11b-9 When wine is exposed to the air, the ethanol in the wine can be oxidized to a compound with the formula

70

C

A HCHO. **B** HCOOH. **C** CH_3COOH. **D** CH_3CH_2COOH.

S11b-10 Aldehydes may be prepared by oxidizing

80

A

A primary alcohols.
B secondary alcohols.
C tertiary alcohols.
D ketones.
E carboxylic acids.

S11b-11 Primary, secondary and tertiary alcohols behave differently when treated with oxidizing agents.

80

C

Of the following, the major organic product formed by oxidation of a **secondary** alcohol is

A a tertiary alcohol.
B an aldehyde.
C a ketone.
D a carboxylic acid.

S11b-12 Oxidation of 2-butanol is likely to result in the formation of

60

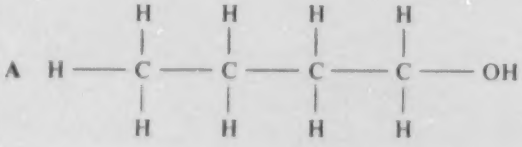
B

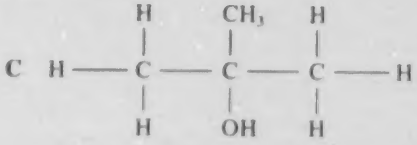
A butanoic acid.
B butanone.
C butanal.
D propanoic acid.

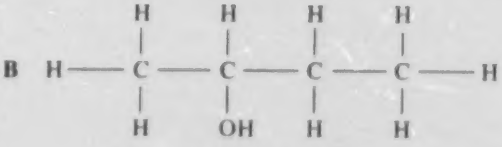
S11b-13 The following structures represent isomers of butanol. Which one is **least** likely to react with acidified potassium dichromate solution at room temperature?

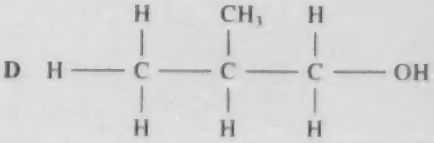
80

C

A 

C 

B 

D 

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S11b-14 80 C

Alcohols may be classified as either primary, secondary or tertiary. Tertiary alcohols may be readily distinguished from primary and secondary alcohols by treatment with

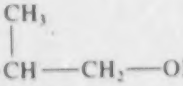
A sodium metal.
B sodium hydrogen carbonate solution.
C acidified potassium dichromate solution.
D bromine solution.

S11b-15 40 C

An acidified solution of potassium dichromate would be **least** likely to react with

A $CH_3(CH_2)_4CH_2OH$.
B $CH_3(CH_2)_3CH(OH)CH_3$.
C $CH_3C(C_2H_5)_2OH$.
D $CH_3CH_2CH(C_2H_5)CH_2OH$.

S11b-16 90 D

A sample of the compound  is mixed with hydrogen bromide and then the mixture is warmed to cause reaction.

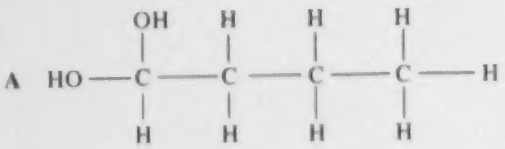
The products of the reaction are

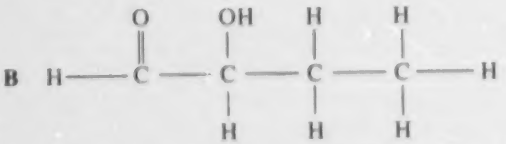
A bromomethane and 1-propanol.
B 1-bromopropane and methanol.
C 2-bromopropane and methanol.
D 1-bromo-2-methylpropane and water.

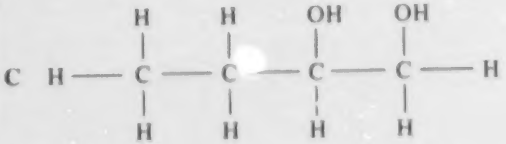
S11b-17 80 C

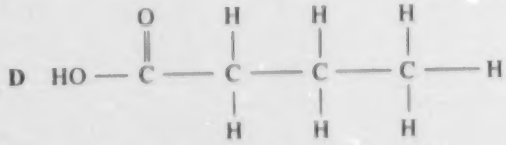
A compound *X* with the molecular formula $C_4H_{10}O_2$ reacted with phosphorus pentachloride to form 1,2-dichlorobutane.

Which of the structures below is most likely to represent the structure of compound *X*?

A 

B 

C 

D 

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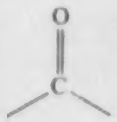
S12 Aldehydes, Ketones

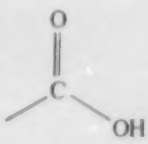
S12a Nature

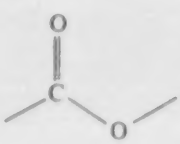
S12a-1 40 **A**

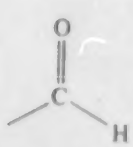
The properties of many organic compounds are determined largely by the chemical properties of small groups of atoms, called functional groups.

The carbonyl functional group is best represented as

A 

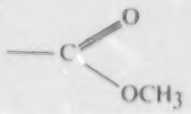
B 

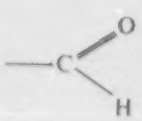
C 

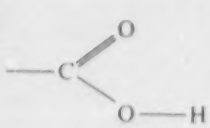
D 

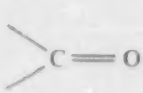
S12a-2 70 **D**

By which one of the following functional groups are ketones characterized?

A 

B 

C 

D 

S12a-3 40* **D**

The reactions and properties of the carbonyl group have been extensively studied by chemists as the group is common in biological molecules.

Which one of the following naturally occurring substances does **not** contain a carbonyl functional group?

A camphor
B progesterone
C vanillin
D cholesterol

S12a-4 70 **C**

Which one of the following formulae could represent a ketone?

A C_3H_8O **B** C_3H_7O **C** C_3H_6O **D** C_3H_5O

S12b Nomenclature

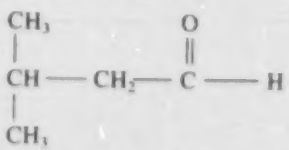
S12b-1 70 **D**

The systematic name for the compound $CH_3\overset{\overset{O}{\|}}{C}CH_2CH_3$ is

A methyl propanone.
B methyl propanoate.
C butanal.
D 2-butanone.

S12b-2 40 **C**

Consider this compound:



Its systematic name is

A 3,3-dimethylpropanal.
B 1,1-dimethylpropanal.
C 3-methylbutanal.
D 1-methylbutanal.

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S12c Structure

S12c-1 | 70 | C

Which one of the following molecules contains a double bond?

A $(CH_3)_2CHCH_3$
B $(CH_3)_3CCH_2CH_3$
C CH_3CH_2CHO
D $(CH_3)_2CHNH_2$

S12d Preparation

S12d-1 | 60 | A

Which one of the following reaction sequences summarizes the steps by which propanal (CH_3CH_2CHO) could be prepared from propane ($CH_3CH_2CH_3$)?

A halogenation followed by hydrolysis and oxidation
B reaction with oxygen at high temperatures
C halogenation followed by alkaline hydrolysis
D halogenation followed by reaction with sodium propoxide ($NaOCH_2CH_2CH_3$)

S12e Properties

S12e-1 | 80 | D

The reaction of acidified potassium dichromate solution with propanal will produce

A propanol.
B propanone.
C propyl chromate.
D propanoic acid.
E propane.

S12e-2 | 40 | D

Which of the following reagents would **certainly not** convert an aldehyde to a carboxylic acid in aqueous solution?

A $KMnO_4$ + acid **B** Ce^{4+} **C** Br_2 **D** Na_2CO_3

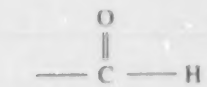
S13 Carboxylic acids

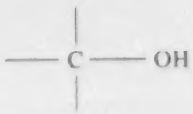
S13a Nature

S13a-1 | 80 | D

The 'sour' taste of fruits is often caused by the presence of carboxylic acids. The functional group responsible for the properties of carboxylic acids is

A

B 

C 

D

S13b Properties

S13b-1 | 40 | A

If equimolar aqueous solutions of the compounds below were prepared, which one would have the lowest pH?

A CH_3COOH **B** CH_3CH_2OH **C** $CH_3CH_2NH_2$ **D** $HOOCCH_2NH_2$

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The next three items refer to the following information

Three organic liquids I, II and III were tested with:

(a) sodium metal;
(b) bromine in dichloromethane;
(c) potassium dichromate in acidified solution.

The results are given in the table.

Liquid	Sodium	Bromine in dichloromethane	Potassium dichromate in acid solution
I	no reaction	no reaction	decolourised
II	gas evolved	no reaction	decolourised
III	gas evolved	decolourised	no reaction

Use the following key to answer the questions below.

A $CH_3\overset{\overset{O}{\|}}{C}CH_3$

B $CH_2{=}CHCOOH$

C CH_3CH_2CHO

D $CH_3CH_2CH_2OH$

E $CH_3{-}\overset{\overset{O}{\|}}{C}{-}CH{=}CH_2$

F CH_3CH_2COOH

S13b-2 50 **C**

Which structural formula could correspond to liquid I?

S13b-3 50 **D**

Which structural formula could correspond to liquid II?

S13b-4 30 **B**

Which structural formula could correspond to liquid III?

S13b-5 70 **D**

Artificial fruit flavourings are made by mixing synthetic esters.

Esters are usually prepared in the laboratory by reaction of

A a carboxylic acid and an aldehyde.
B an aldehyde and an alcohol.
C an aldehyde and a haloalkane.
D an alcohol and a carboxylic acid.

S13b-6 90 **C**

Which of the following compounds are most likely to react to form an ester?

A $CH_3CHOHCH_3$ and CH_3CHO
B CH_3COCH_3 and CH_3COOH
C CH_3CH_2COOH and CH_3OH
D CH_3CHO and CH_3COOH

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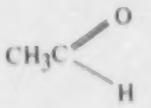
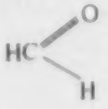
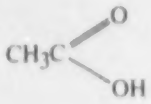
The next two items refer to the following information

A pure organic compound *X* contains carbon, hydrogen and oxygen only. *X* is oxidized with excess acidified potassium permanganate, producing the organic compound *Y*. *X* may be reduced using a suitable reducing agent, and the only organic product is *Z*. When 9.2 g of *Z* is reacted with excess sodium metal at room temperature, 2.24 dm^3 of hydrogen gas is evolved, at STP.

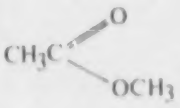
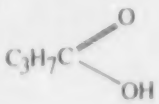
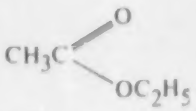
In the presence of a catalyst, *Z* reacts with *Y* to produce the organic product *W*.

(A_r: O = 16, C = 12, H = 1; molar volume of hydrogen gas at STP = 2.4 $dm^3\ mol^{-1}$)

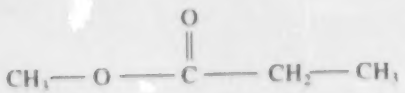
S13b-7 40 **A** On the basis of this information only, *X* is most likely to be

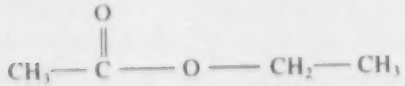
A  **B**  **C**  **D** C_2H_5OH

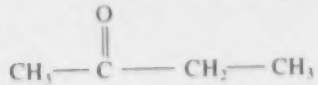
S13b-8 40 **D** On the basis of this information only, *W* is most likely to be

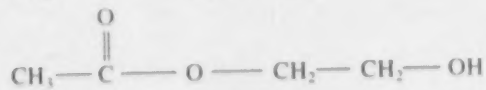
A  **B** C_2H_5OH **C**  **D** 

S13b-9 90 **B** The major product from the reaction between CH_3COOH and CH_3CH_2OH in the presence of sulfuric acid is

A 

B 

C 

D 

S13b-10 50 **C** If propanol, $CH_3CH_2CH_2OH$, is refluxed with ethanoic acid, CH_3COOH, in the presence of concentrated sulfuric acid, one product will be

A propanoic acid.
B ethyl propanoate.
C propyl ethanoate.
D ethanal.

S13b-11 60 **B** During the reaction of ethanol with glacial ethanoic acid to produce ethyl ethanoate, a small amount of sulfuric acid is added to the reaction mixture.

The sulfuric acid is added to

A remove water from the reaction mixture.
B catalyse the reaction.
C prevent hydrolysis of the ethyl ethanoate as it forms.
D aid recovery of the product, ethyl ethanoate, on completion of the reaction.

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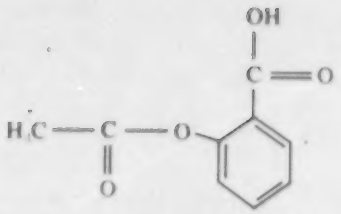
S14 Esters

S14a Nature

S14a-1 40 A — Aspirin, structure



contains the functional groups of

A an acid and an ester.
B an acid and a ketone.
C an ester and a ketone.
D a ketone and an alcohol.

S14a-2 80 A — Fruits like pineapples, bananas and oranges have a characteristic fragrance. This fragrance is mainly due to the presence of

A esters.
B amines.
C ketones.
D aromatic hydrocarbons.

S14a-3 90 D — Which of the following compounds is an ester?

A CH_3CH_2CHO
B CH_3CH_2COOH
C $CH_3CHOHCOCH_3$
D CH_3COOCH_3

S14b Nomenclature

S14b-1 70 D — The compound $CH_3CH_2CH_2COOCH_3$ is a component of pineapple fragrance.

The name of the compound is

A propyl ethanoate.
B butyl methanoate.
C methyl propanoate.
D methyl butanoate.

S14c Properties

S14c-1 30 D — When an organic compound, *A*, is warmed in an aqueous solution containing hydrochloric acid, it decomposes to give two different compounds, *B* and *C*. If the mixture of *B* and *C* is then treated with an acidified solution of potassium dichromate, a single organic compound, *B*, of molecular formula $C_2H_4O_2$ results.

Compound *A* is probably

A $CH_3CH_2COOCH_2CH_3$.
B CH_3COOCH_2COOH.
C CH_3COOCH_3.
D $CH_3COOCH_2CH_3$.

S14c-2 40 A — An organic compound *X* of formula $C_5H_{10}O_2$ forms two compounds when boiled in aqueous sodium hydroxide solution. One of these compounds forms a ketone when treated with acidified potassium dichromate.

Compound *X* could be

A $CH_3COOCH(CH_3)_2$.
B $CH_3CH_2CH_2CH_2COOH$.
C $CH_3CH_2COOCH_2CH_3$.
D $(CH_3)_2CH_2COOCH_3$.

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S14c-3 | Which one of the following pairs of substances is most likely to react to form the compound $CH_3CH_2CO_2Na$?

40
C

A metallic sodium and 1-propanol
B sodium hydroxide and 1-propanol
C sodium hydroxide and methyl propanoate
D metallic sodium and propanone

S15 Fats, Oils, Soaps, Detergents

S15a Nature, Structure

S15a-1 | Fats are used as energy-storing compounds by plants and animals and are widely used in the food industry and in the manufacture of soap.

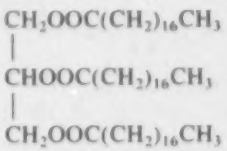
50
C

Fats are best described as high molecular mass

A alcohols.
B hydrocarbons.
C esters.
D carboxylic acids.

S15a-2 | The compound

50
E



is best described as

A a sugar.
B a protein.
C an amino acid.
D a soap.
E a fat.

S15a-3 | Long chain esters are commonly found in

60
D

A anaesthetics.
B proteins.
C insecticides.
D fats.

S15a-4 | A glyceride contains the functional group of

30
B

A an alcohol.
B an ester.
C a carboxylic acid.
D an amide.
E an aldehyde.

S15a-5 | Vegetable oils such as linseed oil were once widely used as the base for paints.

60
A

The molecules in vegetable oils can be described as

A unsaturated esters.
B saturated esters.
C unsaturated alcohols.
D saturated alcohols.

S15a-6 | The fats found in animals and plants are esters of high molecular mass. The usual number of ester groups in a molecule of fat is

30
C

A 1. B 2. C 3. D 4.

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S15a-7 40 **B**

Fats and oils are naturally occurring esters used as energy storing compounds by plants and animals. They can be regarded as being derived from long chain carboxylic acids and the compound

A $H_2NCH_2\overset{\overset{O}{\|}}{C}OH$.

B $HOCH_2CHOHCH_2OH$

C $HOCH_2\overset{\overset{O}{\|}}{C}H$.

D $HO\overset{\overset{O}{\|}}{C}CH_2\overset{\overset{O}{\|}}{C}OH$.

E $CH_3C(OH)_3$.

S15b Properties

S15b-1 40 **B**

The fats found in animals and plants are usually classified in two groups: saturated fats and unsaturated fats.

Compared with saturated fats, unsaturated fats tend to

A contain less ester linkages per molecule.
B melt at lower temperatures.
C be more abundant in warm-blooded animals.
D have larger relative molecular masses.

S15b-2 50 **A**

The conversion of oils to solid fats is one of the main processes in the production of table margarine.

During this process oils are treated with

A $H_2(g)$.
B HCl(aq).
C NaOH(aq).
D $NaHCO_3(aq)$.

S15b-3 30 **A**

Margarine has the advantage over butter that it can be produced cheaply from vegetable oils.

One major process in the production of margarine from vegetable oils involves

A hydrogenation of unsaturated esters.
B dehydrogenation of saturated esters.
C polymerization of unsaturated esters.
D polymerization of saturated esters.

S15b-4 30 **C**

The major reaction involved in the conversion of oils to fats can be classified as

A substitution.
B condensation.
C addition.
D dehydrogenation.
E polymerization.

S15b-5 30 **D**

The amount of NaOH required to completely hydrolyse 1 mol of a glyceride is

A 0.5 mol. **B** 1 mol. **C** 2 mol. **D** 3 mol.

S15b-6 90 **D**

When animal fat is boiled with concentrated sodium hydroxide solution for several hours, molten soap forms on the surface of the mixture.

The reaction is best described as

A hydrogenation.
B esterification.
C polymerization.
D saponification.

S15b-7 70 **B**

A major reaction in the preparation of soap is called saponification. Saponification can best be regarded as the

A neutralization of a carboxylic acid.
B base hydrolysis of an ester.
C oxidation of an aldehyde.
D acid-catalysed dehydration of an alcohol.

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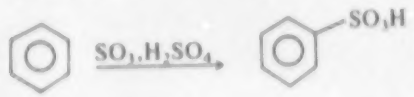
S15b-8 Which of the following reactions is called saponification?

50
A

A $CH_3COOCH_3 + OH^- \rightarrow CH_3COO^- + CH_3OH$

B $CH_3COO^-Na^+ \xrightarrow{HCl} CH_3COOH$

C 

D $CH_3COOH + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3$

S15b-9 Which of the following compounds is a soap?

60
C

A $CH_3(CH_2)_{16}CONa$
B $CH_3(CH_2)_{16}COOH$
C $CH_3(CH_2)_{16}COONa$
D $CH_3(CH_2)_{16}COOCH_3$
E $CH_3(CH_2)_{16}CONH_2$

S15b-10 Synthetic detergents are more soluble than soap and are more effective in hard water.

40
A

Which one of the following compounds is an example of a synthetic detergent?

A $CH_3(CH_2)_{10}CH_2OSO_3^-Na^+$
B $CH_3(CH_2)_{16}COO^-Na^+$
C $CH_3(CH_2)_{12}CH_2O^-Na^+$
D $CH_3(CH_2)_{12}NH_4^+NO_3^-$

S15b-11 Much of the household cleaning that was once performed using soap is now performed using synthetic detergents.

40
B

A major advantage of synthetic detergents over soap is that they

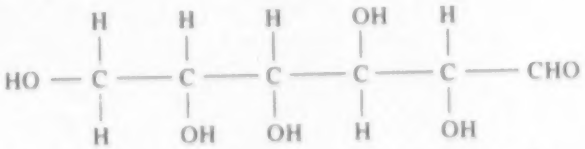
A have a lower resistance to bacterial decomposition.
B form soluble compounds with common metal ions.
C are non-polar and dissolve more readily in grease.
D are more readily synthesized from common fats and oils.

S16 Carbohydrates

S16a Sugars

S16a-1 A molecule of glucose is sometimes represented by the formula

50
C



This is a very poor representation of the structure of glucose in the solid state because

A the –OH groups are arranged on alternate sides of the carbon chain.
B a condensation polymer and water are formed when glucose crystallizes from aqueous solution.
C the molecular structure is based on a ring containing five carbon atoms and one oxygen atom.
D pairs of molecules react to form sucrose, $C_{12}H_{22}O_{11}$, when water is evaporated from a glucose solution.

S16a-2 Glucose, $C_6H_{12}O_6$, is important to life because, in the body, it

70
A

A reacts with oxygen to form CO_2 and H_2O and in so doing releases energy.
B forms part of the sugar-phosphate backbone of DNA.
C is formed by reactions between CO_2 and H_2O in body cells, and subsequently produces energy.
D polymerizes to form proteins.

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S16b Respiration

S16b-1 40 **A**

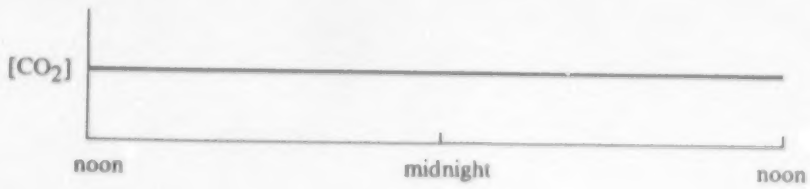
The process of respiration involves the conversion of glucose to carbon dioxide and water. The process involves

A the oxidation of glucose and is exothermic.
B the oxidation of glucose and is endothermic.
C the reduction of glucose and is exothermic.
D the reduction of glucose and is endothermic.
E no redox reaction and is exothermic.
F no redox reaction and is endothermic.

S16b-2 70 **C**

The concentration of CO_2 was measured at tree top level in a forest over a 24 hr period during which the air was still. Which of the four graphs most closely resembles the variation in concentration of the CO_2?

A



B

C

D

S16b-3 80 **A**

Which of the following reactions is the most commonly occurring exothermic process in the majority of living cells?

A $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
B $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
C $n(C_6H_{12}O_6) \rightarrow (C_6H_{10}O_5)_n + nH_2O$
D $C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$

S16c Photosynthesis

S16c-1 90* **C**

The green colour of leaves of plants is due to the presence of a chemical called chlorophyll. The function of chlorophyll is to bring about the conversion of

A cellulose to starch.
B glucose to starch.
C carbon dioxide and water to glucose.
D sugars, phosphate and nitrogen bases to nucleic acids.

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S16c-2 Which of the following equations best represents the overall reaction occurring during photosynthesis?

80

A

A $6H_2O + 6CO_2 + \text{energy} \rightarrow 6O_2 + C_6H_{12}O_6$

B $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

C $C_6H_{12}O_6 + 6CO_2 + \text{energy} \rightarrow 12CO + 6H_2O$

D $12CO + 6H_2O \rightarrow C_6H_{12}O_6 + \text{energy}$

S16c-3 Some living creatures are capable of converting carbon dioxide and water into glucose. This process is

70

D

A exothermic and occurs in the presence of haemoglobin.

B exothermic and occurs in the presence of chlorophyll.

C endothermic and occurs in the presence of haemoglobin.

D endothermic and occurs in the presence of chlorophyll.

S16c-4 The processes of respiration and photosynthesis are of major importance to life in the biosphere. Which one of the following statements about these processes is correct?

70

D

A Both respiration and photosynthesis are occurring continually in plants.

B Photosynthesis involves the conversion of oxygen to glucose whereas respiration produces oxygen.

C Photosynthesis is an exothermic process whereas respiration is an endothermic process.

D Respiration consumes glucose whereas photosynthesis produces glucose.

S16c-5 Which one of the following reactions is **not** likely to occur in most plants?

60

D

A $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

B $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

C $nC_6H_{12}O_6 \rightarrow (C_6H_{10}O_5)_n + nH_2O$

D $2CH_3COOH + 2H_2O \rightarrow 2CH_3CH_2OH + O_2$

S16d Starch, Cellulose

S16d-1 Which one of the following statements does **not** describe a reaction of glucose?

40

B

A Glucose reacts with oxygen exothermically to produce carbon dioxide and water.

B Glucose molecules react exothermically to produce cellulose and water.

C Glucose reacts exothermically to produce carbon dioxide and ethanol.

D Glucose molecules react endothermically to produce starch and water.

S16d-2 Polymers formed by the condensation of glucose are called polysaccharides. Which **one or more** of the following are examples of polysaccharides?

60

C,D

A protein B DNA C cellulose D starch

S16d-3 In which one of the following reactions is water a major product?

30

B

A conversion of starch to glucose

B formulation of cellulose from glucose

C fermentation of glucose

D production of glucose by photosynthesis

S16d-4 Which one of the following compounds could be regarded as the monomer of a condensation polymer?

40

A

A glucose

B ethanamine (ethylamine)

C ethanoic (acetic) acid

D styrene

E vinyl chloride

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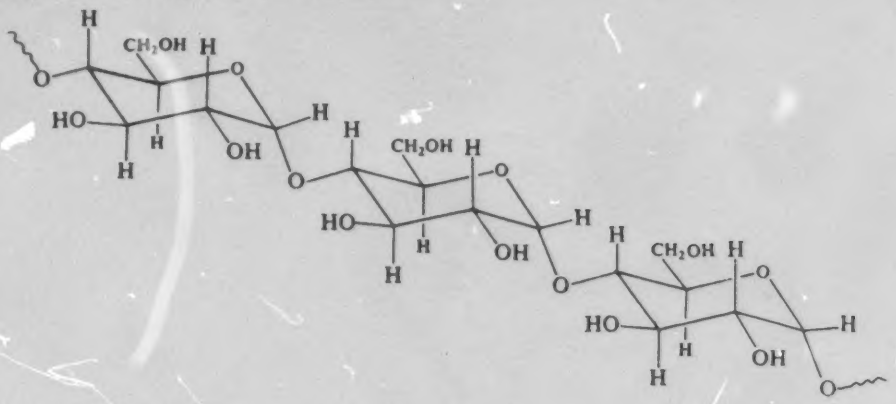
S16d-5 30 **A**

A polymer found in plants has the structure



The monomer for this material is

A glucose.
B alanine.
C cellulose.
D glycine.
E cytosine.

S16d-6 70 **A**

The polymer starch is widely used in the manufacture of foodstuffs and adhesives. It is composed of the elements

A C, H and O only.
B C, H and N only.
C C, H, N and O only.
D C, H, N, O and S.

S16e Fermentation

S16e-1 80 **D**

In the production of beer, yeast cells are added to a mixture of hops and barley. The purpose of the yeast is to

A convert sugar, derived from barley, into carbon dioxide and water, thus giving beer its effervescent nature.
B convert chemicals in hops into small proteins, giving beer a nutrient value.
C break down starch, from the barley, into glucose and carbon dioxide giving beer a high energy content.
D convert sugar, derived from barley, into ethanol, giving beer its alcoholic nature.

S16e-2 50 **C**

The fermentation process used to make beer is

A endothermic and is catalysed by enzymes in yeast.
B endothermic and is catalysed by enzymes in hops.
C exothermic and is catalysed by enzymes in yeast.
D exothermic and is catalysed by enzymes in hops.

S16e-3 90 **D**

During the fermentation process, enzymes

A oxidize the ethanol present in grape juice to ethanoic (acetic) acid.
B convert naturally occurring ethanol to carbon dioxide and water.
C oxidize sugar to ethanoic (acetic) acid with the release of heat energy.
D convert sugar to ethanol and carbon dioxide.

S16e-4 80 **C**

In the fermentation process, enzymes in yeast convert

A glucose into simple sugars.
B cellulose and starch into methanol.
C glucose into ethanol and carbon dioxide.
D water and carbon dioxide into glucose.

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S16e-5
70
A

The fermentation of glucose by yeast yields

A CO_2 and CH_3CH_2OH.
B H_2O and CH_3CH_2OH.
C CH_3COOH and CO_2.
D CH_3COOH and O_2.
E starch.

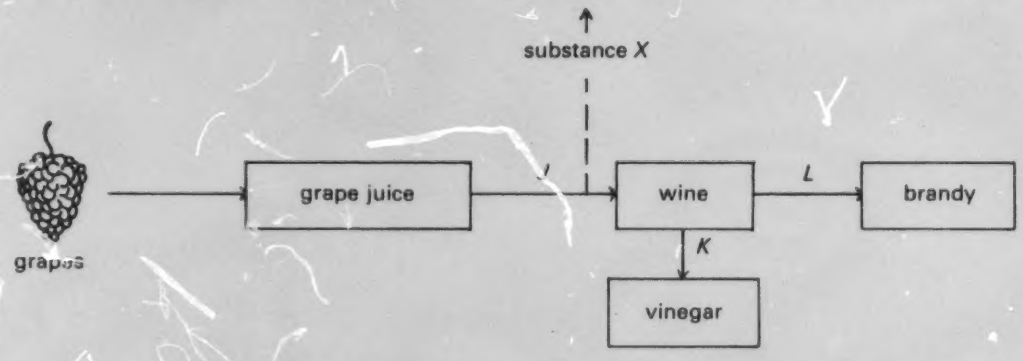
S16e-6
20
C

Bread can be prepared from a mixture of dough, yeast and sugar. Carbon dioxide produced by a reaction within the mixture causes the dough to rise. The other main product from this reaction is likely to be

A CH_3COOH.
B CH_3CHO.
C CH_3CH_2OH.
D $C_6H_{12}O_6$.
E H_2O.

The next four items refer to the following information:

The conversion of grapes to wine, brandy and vinegar can be represented by the following diagram.



Some of the processes represented by the arrows marked *J*, *K* and *L* might be:

I respiration
II distillation
III evaporation
IV fermentation
V oxidation

S16e-7
80
D

The process represented by the arrow labelled *J* is

A I. B II. C III. D IV.

S16e-8
80
B

The process represented by the arrow labelled *L* is

A I. B II. C III. D IV. E V.

S16e-9
80
E

The process represented by the arrow labelled *K* is

A I. B II. C III. D IV. E V.

S16e-10
70
B

The substance *X* given off during process *J* is mainly

A oxygen.
B carbon dioxide.
C sulfur dioxide.
D ethanol vapour.

S17 Insecticides

S17-1
70
D

Two of the major classes of insecticides are the

A chlorinated hydrocarbons and organoamines.
B organosulfates and organophosphates.
C organoamines and organophosphates.
D organophosphates and chlorinated hydrocarbons.
E organoamines and organosulfates.

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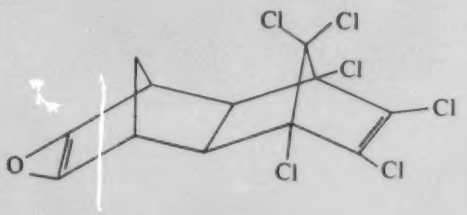
S17-2 70 **A**

A major problem with the use of chlorinated hydrocarbons, such as DDT, as pesticides is that they

A dissolve readily in fat.
B are hydrolysed rapidly in air.
C have a relatively low toxicity.
D act as a nutrient for some bacteria.

S17-3 40 **B**

A range of synthetic insecticides with varying stabilities and solubilities is now available to farmers. One such insecticide, Dieldrin, has the chemical structure shown below.



Dieldrin is

A fat-soluble and biodegradable.
B fat-soluble and non-biodegradable.
C water-soluble and biodegradable.
D water-soluble and non-biodegradable.

S18 Polymers

S18a Monomers, Copolymers, Polymer properties

S18a-1 80 **A**

Which one of the substances below is a copolymer?

A nylon
B poly(styrene)
C natural rubber
D Teflon

S18a-2 60 **C**

A linear polymer is a polymer in which

A no side branches are present.
B the chains are aligned parallel to each other.
C there is no cross linking.
D the atoms are arranged in a row.

S18a-3 50 **B**

A range of mineral oils consists of linear polymers with the general formula C_nH_{2n+2}. For such oils, which of the following would be expected to decrease as the value of n increases?

A boiling temperature
B ease of combustion
C relative molecular mass
D viscosity

S18a-4 60 **B**

Which of the following substances would **not** be likely to act as a monomer?

A $Cl_2C{=}CCl_2$
B $CH_3CH_2CH_2CH_2NH_2$
C $(C_2H_5)_2Si(OH)_2$
D $CH_3Si(OH)_3$

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S18a-5 | As the chain length of polymer molecules increases, the polymer tends to

80

B

A melt at lower temperatures.

B become more viscous.

C become less dense.

D become more soluble in non-polar solvents.

S18b Addition polymers

S18b-1 | If a monomer is to undergo addition polymerisation it should

90

C

A be polar.

B contain both hydrogen and oxygen.

C contain a multiple bond.

B be easily decomposed.

S18b-2 | Which one of the following terms could **not** be used to describe the processes involved in the formation of poly(vinyl chloride) from vinyl chloride?

50

B

A polymerisation

B condensation

C saturation

D addition

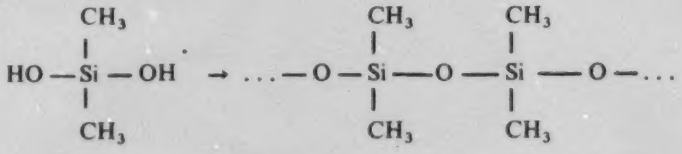
S18b-3 | The structures of monomers and the polymers which can be made from them are shown below. Which polymer is made by addition polymerisation?

80

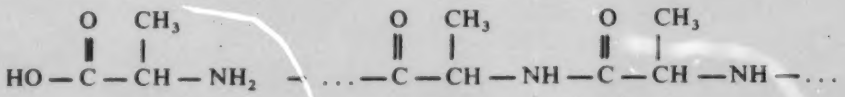
D

MONOMER(S) POLYMER

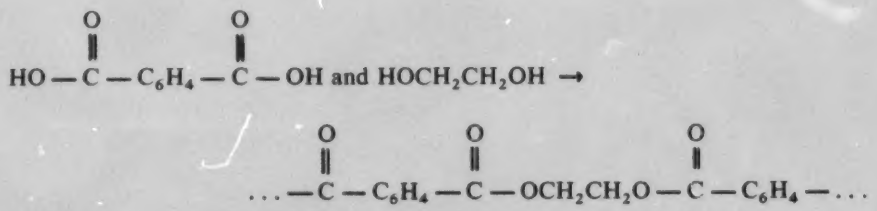
A



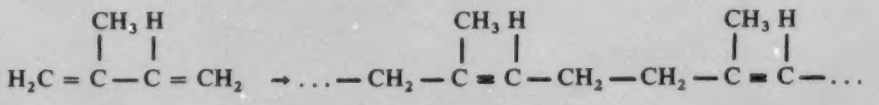
B



C



D



S18b-4 | Which one of the following substances is an addition polymer?

80

C

A starch **B** protein **C** poly(styrene) **D** DNA

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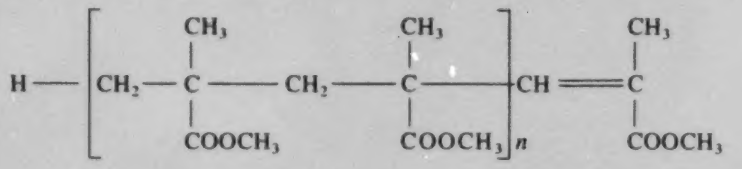
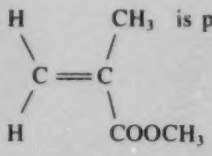
100

S18b-5
40
C

The structure of a polymer used in light fittings can be represented by



The monomer  is produced when the polymer is heated.

The polymer is best regarded as

A a condensation polymer.
B a cross linked polymer.
C an addition polymer.
D a copolymer.

S18b-6
90
A

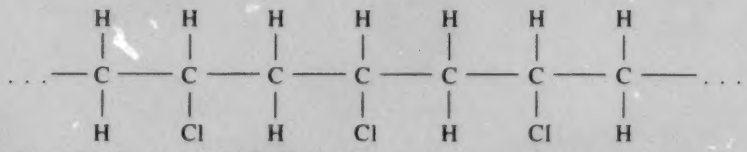
Some polymers are depolymerised when heated. One polymer in particular produces a monomer with the same empirical formula as the polymer.

The polymer in question is likely to be

A an addition polymer.
B a condensation polymer.
C a thermosetting polymer.
D a copolymer.

S18b-7
60
B

A polymer used to make records has the structure



When heated it is converted back to the monomer.

The monomer is

A CH_3CH_2Cl.
B $CHCl=CH_2$.
C $CHCl=CHCl$.
D $CH_2=CHCl-CH_2=CHCl$.
E CH_2ClCH_2Cl.

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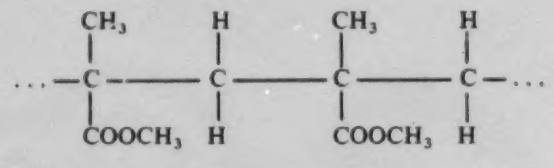
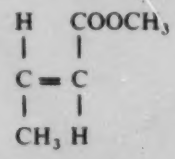
S18b-8
80
C

A polymer used in the manufacture of artificial eyes has the structure



The monomer(s) for this polymer would be

A



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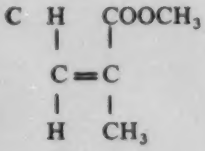

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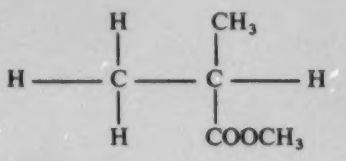

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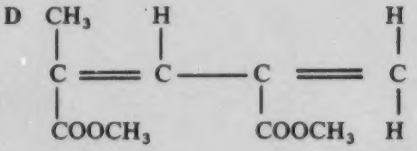


S18b-9
20
A

Poly(butadiene) was once used as a substitute for natural rubber. It is formed from butadiene, $CH_2{=}CH{-}CH{=}CH_2$, under high pressures in the presence of a catalyst. A likely structure for poly(butadiene) is

A . . . $-CH_2-CH=CH-CH_2-CH_2-CH=CH-CH_2-$ . . .

B . . . $-CH_2-CH-CH-CH_2-CH_2-CH-CH-CH_2-$ . . .

C . . . $-CH_2=CH-CH=CH_2-CH_2=CH-CH=CH_2-$ . . .

D . . . $-CH=CH-CH=CH-CH=CH-CH=CH-$ . . .

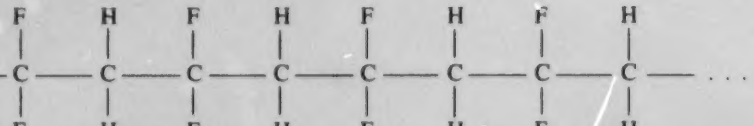
E . . . $-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$ . . .

S18b-10
60
D

Scientists working in a chemistry laboratory discovered that a quantity of tetrafluoroethene gas had converted into a greasy white solid.

This solid would be likely to have the structure

A



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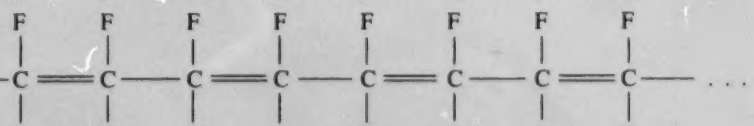

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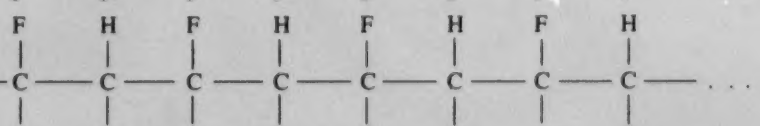

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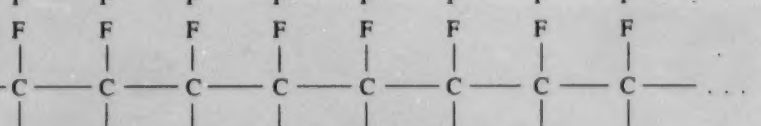

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S18b-11 70 **B**

'Fluon' is the trade name given to a high molecular mass chemical, used as a non-stick coating on kitchenware. It is formed by the reaction, in the presence of a catalyst, of tetrafluoroethene molecules.

In this process

A an addition reaction takes place, with the elimination of water molecules.

B an addition reaction takes place, producing only the polymer and no other products.

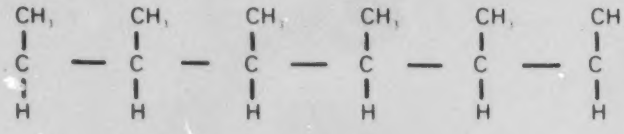
C a condensation reaction takes place, with the elimination of water molecules.

D a condensation reaction takes place, producing only the polymer and no other products.

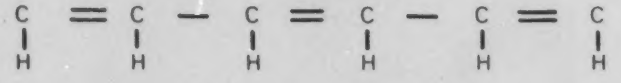
S18b-12 80 **D**

Which one of the following structural formulae represents a segment of a polythene (poly(ethene)) molecule?

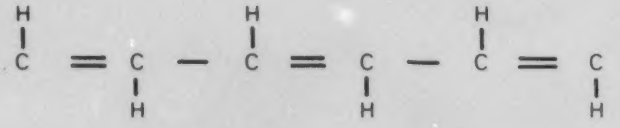
A



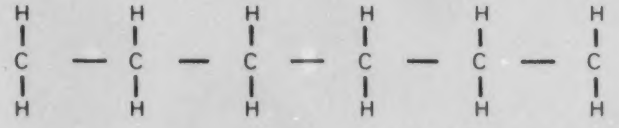
B



C



D



S18b-13 50 **B**

Poly(ethene) can be prepared in low density and high density forms. Low density poly(ethene) is formed using

A high pressures and a Ziegler-Natta catalyst.

B high pressures and an organic peroxide catalyst.

C low pressures and a Ziegler-Natta catalyst.

D low pressures and an organic peroxide catalyst.

S18b-14 70 **B**

The difference in strength between high and low density poly(ethene) is most directly attributable to the

A degree of cross linking.

B degree of side branching.

C relative molecular masses.

D alignment of hydrogen atoms along the chain.

S18b-15 50 **C**

Poly(ethene) can be manufactured in two distinct forms. Form I has a relative molecular mass around 200 000, whereas Form II has a relative molecular mass up to 50 000.

If Form I has a melting temperature of about 135 °C, Form II could melt at

A 170 °C and be more permeable to air.

B 170 °C and be less permeable to air.

C 105 °C and be more permeable to air.

D 105 °C and be less permeable to air.

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S18b-16
60
D

Harsh reaction conditions are used to prepare a soft variety of poly(ethene).

Such conditions cause some C–H bonds to be broken and, as a result,

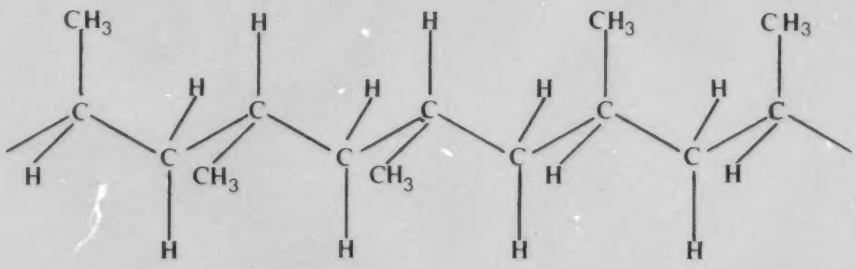
A cross linking of adjacent chains occurs at these points.
B a double bond forms in the polymer chain at these points.
C the polymer chain terminates at these points.
D a branch in the polymer chain occurs at these points.

S18b-17
60*
C

Which of the polymers below would be most suitable for lining the inside of cardboard milk cartons?

A urea–formaldehyde
B perspex
C low density poly(ethene)
D epoxyresin

The next item refers to the following structure



S18b-18
60
C

A polymer with the structure shown above is likely to be

A a copolymer.
B an isotactic polymer.
C an atactic polymer.
D a condensation polymer.

S18b-19
50
B

Propene can polymerise in two different forms, Form I and Form II. In Form I all the side groups lie on the same side of the main chain of the polymer, whereas in Form II the side groups are randomly orientated with respect to the chain.

Which of the following statements about these polymers is correct?

A Form I has more extensive cross linking.
B Form I has stronger dispersion forces between chains.
C Form II has more extensive cross linking.
D Form II has the higher melting temperature.

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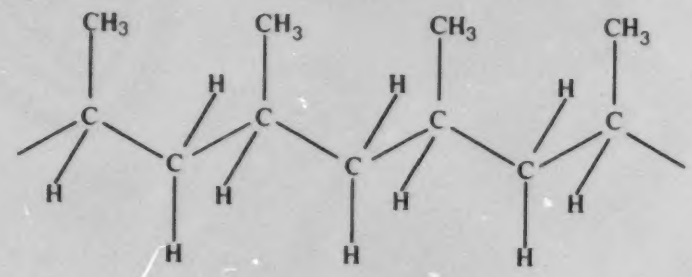
S18b-20 Which one of the following structural formulae best represents isotactic poly(propene)?

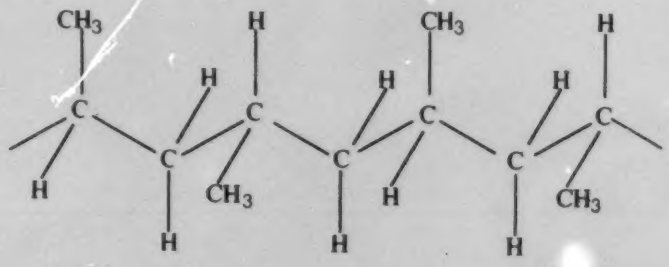
70

A

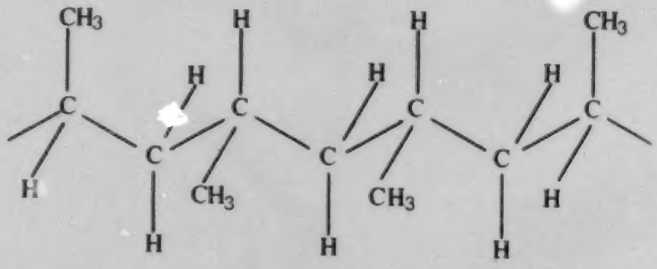
A



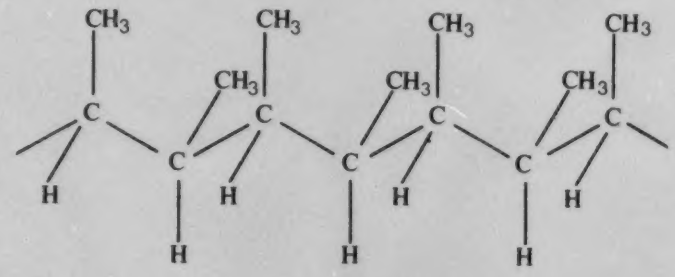
B



C



D



S18b-21 Compared with atactic poly(propene), isotactic poly(propene)

50

D

A has a lower melting temperature.

B is softer.

C has more side branches.

D is formed at lower pressure.

S18b-22 A company producing plastic piping requires a polymer which is very rigid at normal temperatures but can be bent at high temperatures.

60

C

The most appropriate type of polymer for the company to use would be one which was

A atactic and thermoplastic.

B atactic and thermosetting.

C isotactic and thermoplastic.

D isotactic and thermosetting.

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S18b-23
90
D

PVA glue (white glue) is used extensively to join wood surfaces.
The setting of PVA glue is a process which involves

A the formation of hydrogen bonds between chains to produce a hard thermosetting polymer.
B reaction of linear polymer chains with each other to produce an extensively cross linked polymer.
C a chemical reaction between the glue and water vapour from the atmosphere.
D the evaporation of water, leaving behind a mass of tangled linear polymers.

S18c Condensation polymers

S18c-1
70
A

When a polymer is formed by condensation polymerisation

A the mass of polymer formed is less than the combined mass of the reactants.
B it must be a copolymer.
C the product must have a cross linked structure.
D the product must be isotactic.

S18c-2
70
D

Which of the following molecules is most likely to undergo extensive polymerisation with itself?

A $(CH_3)_3COH$
B $H_2N(CH_2)_6NH_2$
C $ClOC(CH_2)_4COCl$
D $H_2N(CH_2)_5COCl$

S18c-3
40
A

Which one of the following compounds could undergo condensation polymerisation reactions with itself?

A alanine
B ethene (ethylene)
C ethanoic (acetic) acid
D benzene

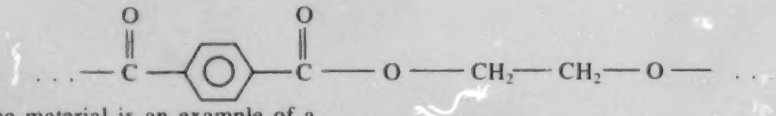
S18c-4
30
A

Which one of the following lists contains only condensation polymers?

A cellulose, protein, starch
B cellulose, Teflon, DNA
C poly(ethene), poly(styrene), poly(vinyl chloride)
D protein, starch, urea

S18c-5
60
B

A material contains long chains made up of the repeating unit

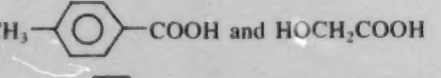
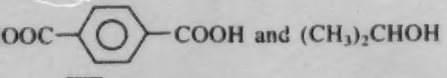
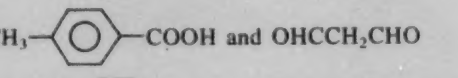
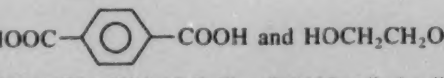


The material is an example of a

A nylon.
B polyester.
C protein.
D poly(styrene).

S18c-6
40
D

Polyesters such as Terylene and Dacron can be used for the construction of swimming pools and car bodies.
Which of the following compounds react to form a polyester?

A 
B 
C 
D 

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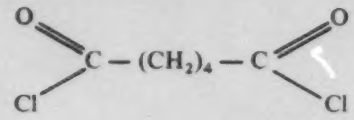
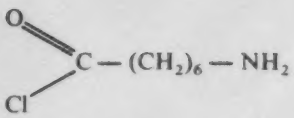
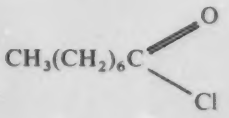
The next two items refer to the following compounds

I 

III 

II $NH_2 - (CH_2)_6 - NH_2$

IV 

S18c-7 40 C

Which one of these compounds (under appropriate temperature and catalytic conditions) would polymerise by itself?

A I **B** II **C** III **D** IV

S18c-8 60 C

Which two of these compounds could polymerise to produce nylon 6.6?

A I and IV **C** I and II
B II and III **D** I and III

S18c-9 70 A

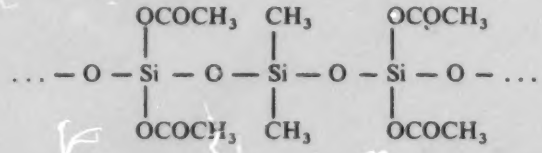
Fibres formed from isotactic poly(propene) are not as strong as fibres formed from nylon. This is mainly a consequence of

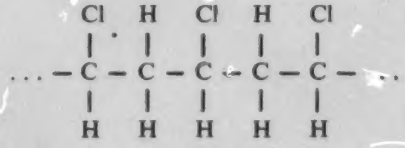
A hydrogen bonding between nylon chains.
B the random arrangement of CH_3- side chains in poly(propene).
C extensive branching of the poly(propene) chains.
D cross linking between nylon chains.

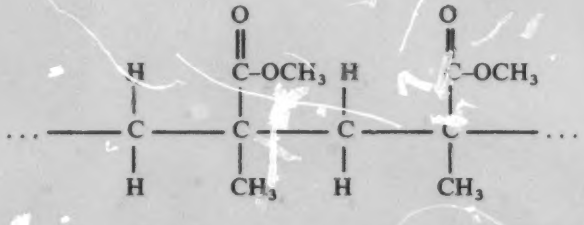
S18c-10 50 D

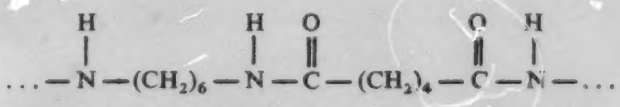
Hydrogen bonding between adjacent chains enhances the fibre strength of some polymers. The structures of four polymers are represented below.

In which case could hydrogen bonding occur between chains?

A 

B 

C 

D 

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S18c-11
50
B

The elastic properties of nylon can be improved by mildly heating it, and gently stretching the thread at the same time.

The best explanation for this is that

A the heat supplied is sufficient to overcome the weak bonding forces in the chains, thus creating smaller but more tangled fragments.

B this procedure causes greater regularity in the lining up of the long chains, and therefore more hydrogen bonding.

C the heat causes reaction between side groups on the nylon chain, increasing the extent of cross linking.

D the chains vibrate more rapidly and become tangled. The subsequent stretching tightens the tangled chains.

S18d Cross linked polymers

S18d-1
70
D

Addition of a catalyst to some mixtures of linear polymers can cause chemical bonds to form **between** the polymers.

The resulting compound is said to be

A atactic.
B isotactic.
C thermoplastic.
D thermosetting.

S18d-2
60
A

In a cross linked polymer the **major** force holding the chains together is due to

A covalent bonding.
B dispersion forces.
C hydrogen bonding.
D attraction between permanent dipoles.

S18d-3
90
D

Cross linked polymers and linear polymers exhibit different physical properties.

Cross linked polymers are usually relatively

A soft and melt when heated.
B soft and do not melt when heated.
C hard and melt when heated.
D hard and do not melt when heated.

S18d-4
90
C

Which one of the following polymers is thermosetting?

A Teflon
B nylon
C urea-formaldehyde
D poly(styrene)

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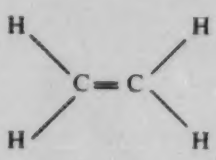
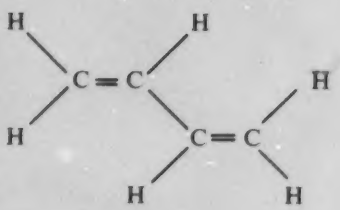
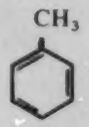
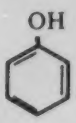
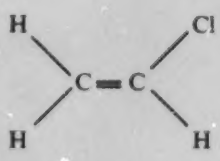
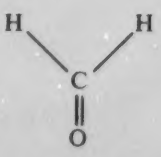
I 

IV 

II 

V 

III 

VI 

S18d-5 60 **D**

Which of the pairs of compounds below is likely to readily form a condensation polymer?

A I and IV
B I and III
C III and V
D V and VI

S18d-6 30 **B**

One of the compounds forms an addition polymer which can then be cross linked using another substance. Which one?

A III **B** IV **C** V **D** VI

S18d-7 40 **B**

Which of the pairs of compounds below is likely to form a copolymer?

A I and V
B I and III
C IV and V
D II and VI

S18d-8 70 **A**

Which one of the following lists contains only thermosetting polymers?

A phenol–formaldehyde; epoxyresin; silicone resin
B nylon; epoxyresin; silicone fluid
C nylon; phenol–formaldehyde; poly(propene)
D phenol–formaldehyde; poly(propene); silicone resin

S18d-9 30 **A**

Which of the following combinations of compounds is most likely to react to form a cross linked polymer?

A $HCHO$ and $(NH_2)_2CO$
B $H_2N(CH_2)_6NH_2$ and $ClCO(CH_2)_4COCl$
C $CH_3CH=CH_2$ and $CF_2=CF_2$
D $(CH_3)_2Si(OH)_2$ and $(CH_3)_3SiOH$

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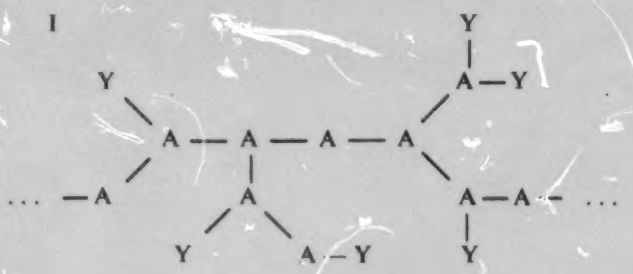
The structures of five polymers are represented by the simplified formulae below.

I



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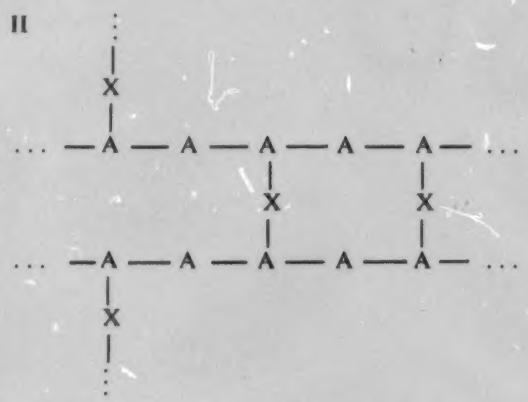

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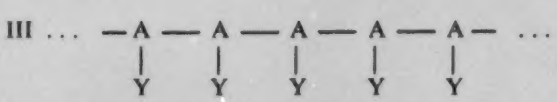

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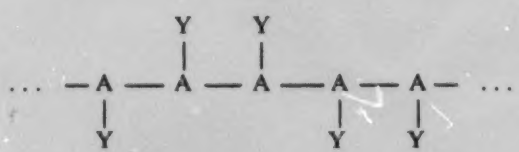

A represents a hydrocarbon group (e.g. CH_2 or CH), X represents a cross linking group of atoms and Y represents an alkyl group (e.g. CH_3).

S18d-10 Which of these polymers could be isotactic?

60

C **A** I **B** II **C** III **D** IV

S18d-11 Which of these polymers is thermosetting?

70

B **A** I **B** II **C** III **D** IV

S18d-12 Which of these polymers would form the strongest fibres?

20

C **A** I **B** II **C** III **D** IV

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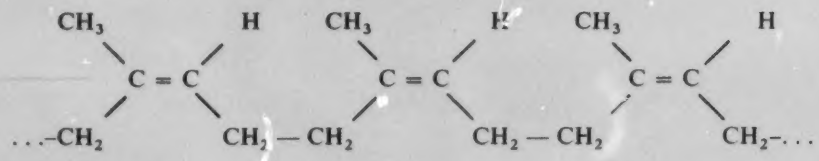
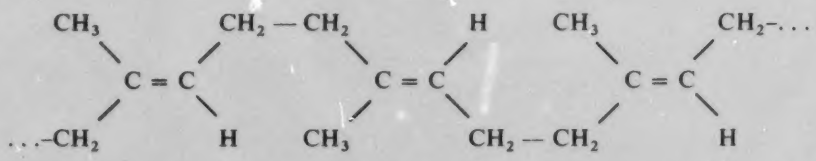
S18e-1 50 **A**

The structure of natural rubber is best represented by

A



B



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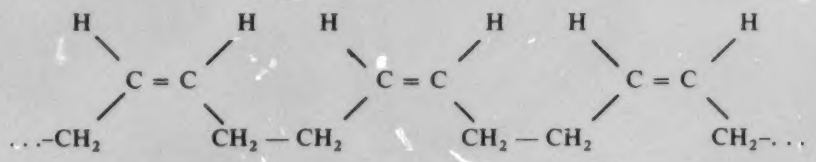

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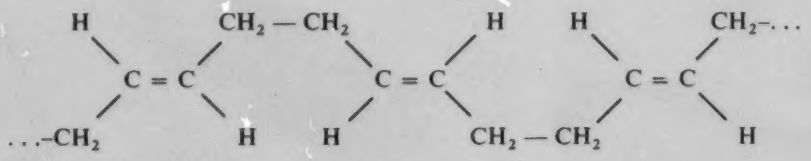

S18e-2 60 **A**

Natural rubber can be regarded as a polymer of isoprene molecules. It is frequently vulcanized before it is used in industry.

The formation of rubber from isoprene and the subsequent vulcanization process can be described as

A addition polymerization followed by an addition reaction.
B addition polymerization followed by a substitution reaction.
C condensation polymerization followed by an addition reaction.
D condensation polymerization followed by a substitution reaction.

S18e-3 80 **D**

Vulcanized rubber softens at a much higher temperature than unvulcanized rubber. This is mainly because in vulcanized rubber

A the average hydrocarbon chain length is larger.
B the chains have an isotactic configuration.
C there are stronger dispersion forces between chains.
D the chains are partially cross linked.

S18e-4 50 **A**

Rubber is used to make car battery cases and elastic bands. The approximate percentages of sulfur in battery cases and elastic bands are likely to be, respectively,

A 30% and 1%.
B 30% and 0%.
C 0% and 30%.
D 1% and 30%.
E 1% and 0%.

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S18e-5 | The major synthetic rubber used to-day is prepared from
40
C

A butadiene.
B isoprene.
C butadiene and styrene.
D isoprene and butadiene.

S19 Carbon dioxide

S19a Production

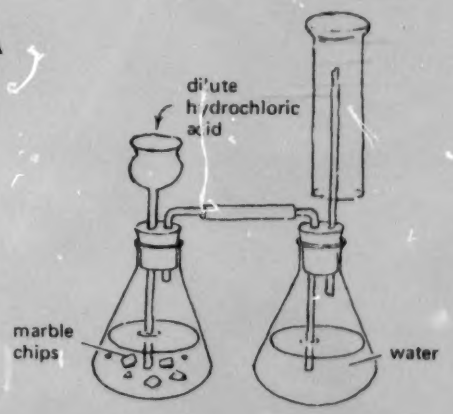
S19a-1 | Which of the following procedures would be most suitable for the production of carbon dioxide (given A_r C=12; M_r O_2=32)?
70
C

A addition of NaOH to $NaHCO_3$ solution
B combustion of 3 g of carbon in 4 g of oxygen
C addition of hydrochloric acid to limestone
D action of air on a glucose solution

S19a-2 | All of the following methods can be used to prepare carbon dioxide, **except** one. Which one?
50
C

A add hydrochloric acid to calcium carbonate
B add sulfuric acid to sodium hydrogen carbonate
C add barium hydroxide to magnesium carbonate
D heat calcium carbonate

S19a-3 | Which one of the following sets of apparatus would be most suitable for preparing carbon dioxide?
60
D

A


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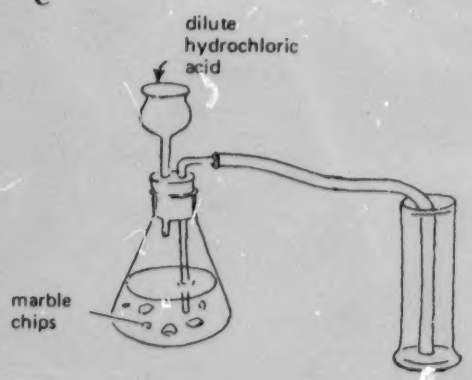

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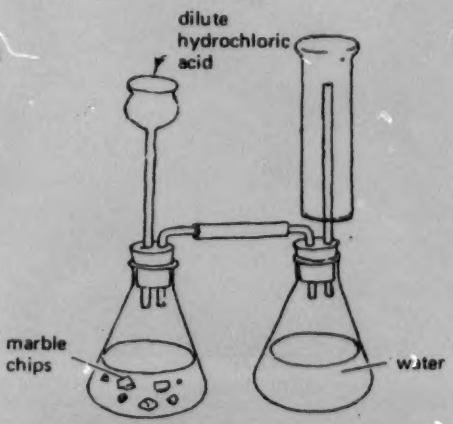

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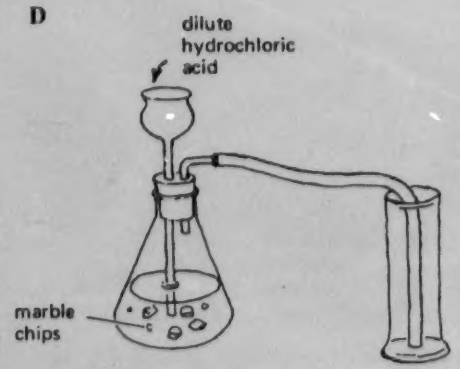

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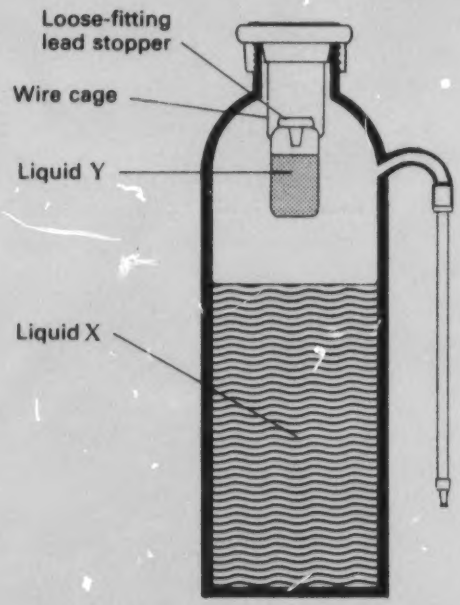
The next two items refer to the following information

The diagram below shows the components of a fire extinguisher suitable for use on wood fires.



S19a-4 30 **D**

The best substances to use for Liquid *X* and Liquid *Y* would be

A calcium carbonate solution and hydrochloric acid.
B sodium hydrogen carbonate solution and sodium hydroxide solution.
C carbonic acid and sodium hydroxide solution.
D sodium carbonate solution and sulfuric acid.

S19a-5 50* **C**

In order to operate the extinguisher in the correct manner, it should be inverted

A so that the CO_2 gas produced is forced through the nozzle at the fire.
B and quickly turned upright, so that the CO_2 gas produced is forced through the nozzle at the fire.
C so that the CO_2 gas produced forces the liquid through the nozzle at the fire.
D and quickly turned upright, so that the CO_2 gas produced forces the liquid through the nozzle at the fire.

S19a-6 80 **B**

Which of the following **would not** be a source of carbon dioxide?

A fermentation of sugar to alcohols
B photosynthesis
C the production of calcium oxide from limestone
D the burning of fossil fuels
E respiration

S19a-7 80 **D**

In which of the following processes does CO_2 **not** play an important role?

A photosynthesis
B combustion of hydrocarbons
C respiration
D petroleum refining

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113

S19b-1
40
A

The following are terms which could describe the properties of a substance:

1 more soluble in water than oxygen
2 less soluble in water than oxygen
3 denser than air
4 less dense than air

Which of these are properties of carbon dioxide?

A 1, 3 **B** 1, 4 **C** 2, 3 **D** 2, 4

S19b-2
60
D

One of the following oxides dissolves in water to form an acidic solution. Which one?

A Na_2O_2 **B** MgO **C** NO **D** CO_2

S19b-3
20
C

The aqueous chemistry of carbon dioxide is of major importance to life on earth. Which of the following sets lists species present in an aqueous solution of carbon dioxide in order of their abundance (increasing from left to right)?

A CO_3^{2-}, HCO_3^-, CO_2, H_3O^+
B HCO_3^-, H_3O^+, CO_3^{2-}, CO_2
C CO_3^{2-}, HCO_3^-, H_3O^+, CO_2
D CO_2, HCO_3^-, CO_3^{2-}, H_3O^+
E CO_3^{2-}, H_3O^+, HCO_3^-, CO_2

S19b-4
30
A

Which one of the substances below is most likely to decompose when gently heated?

A H_2CO_3 **B** H_3PO_4 **C** NH_3 **D** H_2SO_4

S19b-5
90
C

Which one of the following gases will turn lime water cloudy?

A hydrogen
B nitrogen dioxide
C carbon dioxide
D ammonia

S19b-6
80
B

Which one of the following solutions turns cloudy when carbon dioxide is bubbled through it?

A carbonic acid
B calcium hydroxide
C hydrochloric acid
D ammonia

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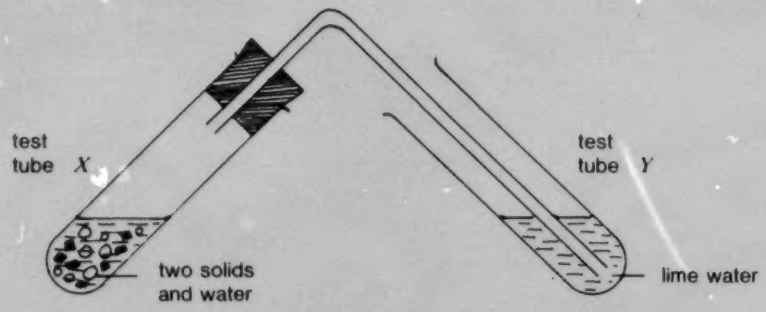
1114

The next two items refer to the following information

Two test tubes were connected by glass tubing, as represented in the diagram below.



A mixture of two solids and water was placed in test tube *X*, and a lime water solution was placed in test tube *Y*. No gas was produced in *X* until the water was added to the solid mixture. The gas produced turned the lime water cloudy.

S19b-7
50
B

Which of the following is a possible explanation of the lime water turning cloudy?

A calcium hydrogen carbonate was converted to calcium carbonate
B calcium hydroxide was converted to calcium carbonate
C calcium carbonate was converted to calcium hydrogen carbonate
D calcium hydroxide was converted to calcium hydrogen carbonate

S19b-8
10
D

The two solids in test tube *X* could have been

A sodium carbonate and silicon dioxide.
B calcium hydrogen carbonate and ethanoic (acetic) acid.
C sodium carbonate and sulfuric acid.
D sodium carbonate and phosphorus(V) oxide.
E sodium hydroxide and sodium carbonate.

S19b-9
70*
C

A common test for determining if a gas contains CO_2 is to bubble the gas through a solution of $Ca(OH)_2$. If CO_2 is present the solution becomes cloudy because

A insoluble $Ca(HCO_3)_2$ is formed.
B dissolved CO_2 increases the concentration of OH^-, producing a $Ca(OH)_2$ precipitate.
C insoluble $CaCO_3$ is formed.
D insoluble CaO and carbonic acid, H_2CO_3, are produced.

S19b-10
40
B

The equation $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$ best represents the reaction which occurs

A when quicklime is exposed to the atmosphere.
B when lime water turns from cloudy back to clear.
C in the production of lime from limestone.
D when lime water turns cloudy.

S19b-11
50
B

When carbon dioxide is bubbled into lime water a white precipitate forms which dissolves upon the further addition of carbon dioxide. The soluble substance produced is

A calcium oxide.
B calcium hydrogen carbonate.
C calcium hydroxide.
D calcium carbonate.

S19b-12
60
A

Calcium carbonate, $CaCO_3$, is sparingly soluble in water but, when an aqueous suspension of $CaCO_3$ is treated with excess CO_2, the solid dissolves. This is because of the formation of

A $Ca(HCO_3)_2(aq)$. **B** $CaO(aq)$. **C** $CaC_2(aq)$. **D** $Ca(OH)_2(aq)$.

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S19b-13 50* **B**

The equation $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$ best represents the reaction that occurs when

A lime water turns milky.
B limestone dissolves to form caves.
C lime water is prepared from limestone.
D quicklime is exposed to the atmosphere.

S19b-14 60 **A**

Which of the following substances is the most effective for removing carbon dioxide from air?

A sodium hydroxide
B concentrated sulfuric acid
C hydrogen sulfide
D phosphorus(V) oxide

S19b-15 30 **A**

The CO_2 content of the air in a manned space capsule must be kept at a low level to safeguard the occupants. Which of the following would probably be chosen as an efficient CO_2 removing agent for a space flight?

(A_r: H=1, Li=7, O=16, Na=23, K=39, Ba=137)

A 10 kg of LiOH
B 10 kg of NaOH
C 10 kg of $Ba(OH)_2$
D 10 kg of KOH

S19b-16 50 **B**

Oxalic acid ($H_2C_2O_4$) reacts with concentrated sulfuric acid (H_2SO_4) as follows:

$$H_2C_2O_4 + H_2SO_4 \rightarrow H_3O^+ + HSO_4^- + CO + CO_2$$

A sample of pure carbon monoxide could be obtained by purifying the gaseous products with

A H_2SO_4 solution.
B $Ca(OH)_2$ solution.
C $CaCl_2$ solution.
D $K_2Cr_2O_7$ solution.

S20 Carbonates, Hydrogen carbonates

S20a Occurrence

S20a-1 60 **D**

Calcium carbonate is widely distributed in nature. It is the major constituent of all the following substances **except** one. Which one?

A limestone
B sea shells
C stalactites
D bone

S20b Properties, Uses

S20b-1 10 **D**

Which one of the following substances does **not** exist as a solid at room temperature?

A calcium orthophosphate
B ammonium nitrate
C phosphorus(V) oxide
D calcium hydrogen carbonate

S20b-2 80 **B**

Addition of hydrochloric acid to calcium carbonate yields

A calcium chloride, water and carbon monoxide.
B calcium chloride, water and carbon dioxide.
C calcium oxide, water and carbon dioxide.
D calcium hydroxide and carbon dioxide.

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S20b-3 90 **C**

Most buildings constructed of quarried limestone show deterioration after a few years.
A possible explanation of this phenomenon is that

A water reacts with calcium carbonate releasing carbon dioxide and leaving a deposit of brittle calcium hydrogen carbonate.

B carbon dioxide reacts with calcium oxide impurities in limestone, to produce reactive hydrogen carbonate ions.

C water combines with atmospheric carbon dioxide, forming carbonic acid, which, in turn, reacts with calcium carbonate to form soluble calcium hydrogen carbonate.

D water combines with calcium carbonate to form the strong base calcium hydroxide, which reacts with acidic impurities in the limestone.

S20b-4 50 **B**

Marble statues in the open air often show signs of chemical weathering after a number of years.
The most likely explanation for this is that

A the calcium hydrogen carbonate in the marble reacts with dissolved CO_2 in rain water.

B H_3O^+ ions present in rain water react with the CO_3^{2-} ions present in the marble.

C the HCO_3^- ion undergoes both acid and base hydrolysis in the presence of water.

D the insoluble CO_3^{2-} ions are oxidized by dissolved O_2 to soluble HCO_3^- ions.

S20b-5 40 **C**

30 cm^3 of 2.0 M nitric acid is needed to completely react with a sample of impure limestone containing 40% calcium carbonate by mass. Assuming calcium carbonate to be the only substance reacting with the acid, the mass of the impure limestone is (given A_r: Ca=40, O=16, C=12)

A 1.2 g. **B** 3.0 g. **C** 7.5 g. **D** 15 g. **E** 30 g.

S20b-6 40 **B**

Consider the reaction represented by the following equation.

$$Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2O + CO_2$$

The forward reaction occurs when

A limestone is dissolved to form caves.

B stalactites are formed.

C hard water is passed through a water-softening device.

D limestone is heated in a kiln.

E lime water turns milky.

S20b-7 60* **C**

Calcium carbonate is the second most abundant mineral in the earth's crust, and is used in a variety of ways by industry. It is not usually used in the

A production of soda glass.

B extraction of iron from iron ore.

C production of phosphorus.

D production of cement.

S20b-8 20* **B**

Large quantities of slaked lime, $Ca(OH)_2$, are manufactured from limestone for use in the preparation of mortar. Slaked lime is usually prepared by

A adding concentrated sulfuric acid to limestone and treating the product with sodium hydroxide solution.

B heating limestone and treating the product with water.

C adding concentrated sodium hydroxide solution to limestone and evaporating the water.

D heating limestone and treating the product with sodium hydroxide solution.

S20b-9 60 **B**

In order to make bread dough rise, a baker may use flour containing added chemicals.
Which *one* of the following could be *satisfactorily* used by the baker?

A Na_2CO_3

B $NaHCO_3$

C $CaCO_3$

D $Ca(HCO_3)_2$

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S20b-10 60 **B**

Sodium hydrogen carbonate is commonly used

A to soften hard water.
B as a raising agent in cooking.
C to harden soda glass.
D in the manufacture of cement.

S20c Hard water

S20c-1 60 **D**

Washing soda, $Na_2CO_3.10H_2O$, is a white crystalline solid which is used as a water softener. Washing soda softens water by

A reacting with H^+ ions to form bubbles of CO_2 gas.
B converting H^+ ions to less acidic HCO_3^- ions.
C removing dissolved oxygen in the form of CO_2 gas.
D precipitating Ca^{2+} and Mg^{2+} ions present in solution.

S20c-2 60 **C**

In some Australian cities it is difficult to form a lather when soap is shaken with tap water. This is likely to be due to the presence of

A sodium ions.
B hydroxide ions.
C calcium ions.
D carbonate ions.
E dissolved carbon dioxide.

S20c-3 30 **D**

A clear sample of well water produced a white precipitate when added to calcium hydroxide solution (lime water). Which one of the following substances is most likely to have been responsible for causing the precipitate?

A sodium chloride
B calcium carbonate
C calcium phosphate
D magnesium hydrogen carbonate

S20c-4 30 **A**

Temporary hardness in water can be removed by boiling the water. This is because

A soluble hydrogen carbonates are thermally decomposed to insoluble carbonates.
B calcium hydrogen carbonate decomposes on heating to soluble calcium hydroxide.
C calcium compounds dissolved in the water dehydrate on heating.
D calcium carbonate decomposes on heating to give calcium oxide and carbon dioxide.

S21 Carbon monoxide

S21-1 10 **C**

The lid of a gas jar containing one gas only was removed and a burning match was dropped into the jar. The match went out but the gas burnt with a blue flame. The gas in the jar was most likely to be

A oxygen.
B nitrogen dioxide.
C carbon monoxide.
D sulfur trioxide.

S21-2 50 **B**

Which of the following statements concerning carbon monoxide gas is **incorrect?**

Carbon monoxide

A can be used to reduce iron oxide to iron.
B reacts with excess sodium hydroxide in solution to form sodium carbonate.
C is a colourless, odourless gas.
D can readily combine with haemoglobin to form a relatively stable compound.

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S21-3
90
A

People intent on suicide may lock themselves in a confined space, and allow fumes from an internal combustion engine to fill the space.

High exhaust fume concentrations lead to death because

A carbon monoxide combines more extensively with haemoglobin than does oxygen, thus starving the tissues of oxygen.

B increased exhaust fume concentrations greatly lower the oxygen concentration in the air, causing death by asphyxiation.

C carbon dioxide dissolves in blood forming carbonic acid, causing death by acidosis.

D carbon monoxide and carbon dioxide dissolve more readily in blood than does oxygen, causing oxygen starvation in the tissues.

S21-4
40
C

When oxygen is given to patients suffering from carbon monoxide poisoning, it

A has a greater affinity for haemoglobin than does CO, and hence CO is removed from the bloodstream.

B oxidizes CO in the blood to CO_2.

C shifts the equilibrium in the reaction O_2 + haemoglobin/CO $\rightleftharpoons$ haemoglobin/O_2 + CO, to the right.

D increases the concentration of O_2 dissolved in the blood, and hence lowers the concentration of CO in the blood.

S21-5
80
C

Carbon monoxide, CO, is poisonous to humans because it

A reacts with O_2 in body tissues, thereby depriving the body of oxygen.

B reacts with water in the blood, forming the poisonous substance formic acid.

C interferes with the means whereby O_2 is transported around the body, thereby depriving the body of oxygen.

D interferes with the enzyme that catalyses the release of CO_2 from the bloodstream, causing a fatal drop in blood pH.

S21-6
60
C

Carbon monoxide and oxygen can both form complexes with haemoglobin, Hb_4, in the blood as shown below:

I $Hb_4 + 4O_2 \rightleftharpoons Hb_4O_8$

II $Hb_4 + 4CO \rightleftharpoons Hb_4(CO)_4$

Carbon monoxide is poisonous because

A the rate of reaction II is much greater than that of reaction I.

B reaction II is much easier to reverse than reaction I.

C the equilibrium constant for reaction II is much greater than that of reaction I.

D $Hb_4(CO)_4$ is much larger than Hb_4O_8, restricting its transportation rate in the bloodstream.

S21-7
30
A

Which of the following reactions involving haemoglobin, Hb_4, has the smallest equilibrium constant at blood heat (≈37 °C)?

A $Hb_4 + 4CO_2 \rightleftharpoons Hb_4(CO_2)_4$

B $Hb_4 + 4O_2 \rightleftharpoons Hb_4(O_2)_4$

C $Hb_4(O_2)_4 + 4CO \rightleftharpoons Hb_4(CO)_4 + 4O_2$

D $Hb_4 + 4CO \rightleftharpoons Hb_4(CO)_4$

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T SILICON CHEMISTRY

T1 Silanes

T1-1 | 50 | C

The angles between bonds in silane are about

A 180°. **B** 120°. **C** 109°. **D** 90°.

T1-2 | 30* | E

Which of the following compounds is the most unstable in air?

A NH_3 **B** Na_2SiO_3 **C** SiO_2 **D** SH_2 **E** SiH_4

T1-3 | 60 | B

Silane will burn spontaneously in air, yet methane has to be ignited.
This difference can be attributed to

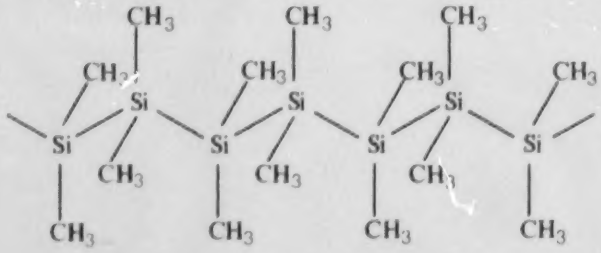
A Si–H bonds being stronger than C–H bonds and SiO_2 being more stable than CO_2.
B Si–H bonds being weaker than C–H bonds and SiO_2 being more stable than CO_2.
C Si–H bonds being stronger than C–H bonds and SiO_2 being less stable than CO_2.
D Si–H bonds being weaker than C–H bonds and SiO_2 being less stable than CO_2.

T2 Silicon polymers

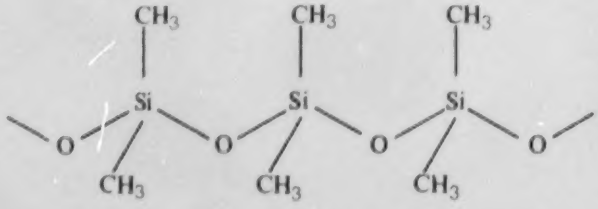
T2-1 | 80 | B

Which one of the following structures could represent a part of a silicone?

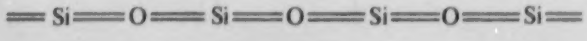
A



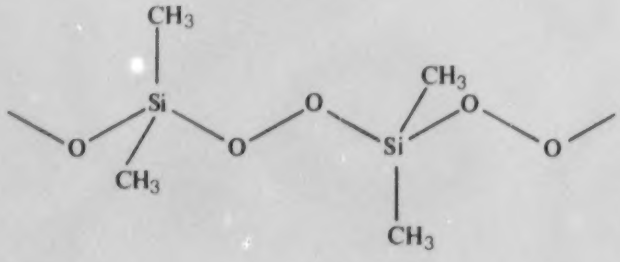
B



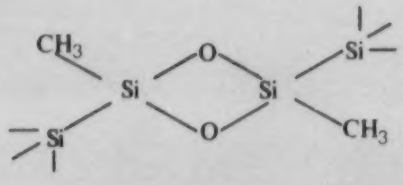
C



D



E



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T2-2
80
C

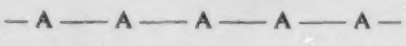
Which one of the following is **not** true of silicone fluids?

A They are insoluble in water.
B They are stable at high temperatures.
C They are good electrical conductors.
D Their properties depend on the polymer chain length.

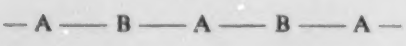
The next three items refer to the following information

Four types of polymer can be represented by the simplified formulae below.

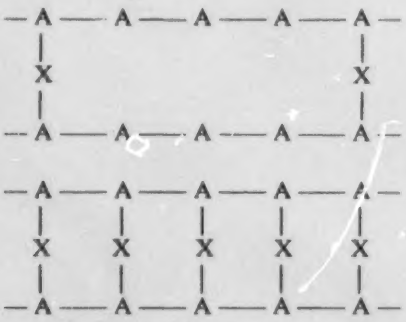
I



II



III



A and B represent repeating units derived from different monomers and X represents a cross linking atom or group of atoms.

T2-3
90
B

Which one of these formulae could represent a copolymer?

A I **B** II **C** III **D** IV

T2-4
20
A

Which one of these formulae could represent the silicon polymer produced from the hydrolysis of $(CH_3)_2SiCl_2$?

A I **B** II **C** III **D** IV

T2-5
80
C

Which one of these formulae best represents vulcanised natural rubber?

A I **B** II **C** III **D** IV

T2-6
40
C

The percentage by mass of silicon in the compound $(CH_3)_2Si(OH)_2$ is 30·5 %. This compound polymerises, forming a silicone polymer. The percentage by mass of silicon in the polymer would be

A 30·5 % .
B less than 30·5 % .
C more than 30·5 % .
D either **A**, **B** or **C**, depending upon the degree of polymerisation.

T2-7
40
C

A cross linked silicon polymer can be prepared by adding water to a mixture of $(CH_3)_3SiCl$, $(CH_3)_2SiCl_2$ and CH_3SiCl_3.

The amount of cross linking in the polymer is increased by increasing the proportion of

A $(CH_3)_3SiCl$.
B $(CH_3)_2SiCl_2$.
C CH_3SiCl_3.
D water.

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T2-8 50 **B**

If the chlorosilanes $(C_2H_5)_3SiCl$ and $(C_2H_5)_2SiCl_2$ were mixed and hydrolysed, the relative molecular mass of the polymer produced would be greatest if

A the amount of $(C_2H_5)_3SiCl$ were greater than the amount of $(C_2H_5)_2SiCl_2$.
B the amount of $(C_2H_5)_3SiCl$ were less than the amount of $(C_2H_5)_2SiCl_2$.
C the amounts of $(C_2H_5)_3SiCl$ and $(C_2H_5)_2SiCl_2$ were equal.

T2-9 50 **D**

Methyl hydroxysilanes readily undergo condensation reactions to form polymers. Which of the following molecules is most likely to cause termination of a linear polymer chain in such a reaction?

A $Si(OH)_4$
B $CH_3Si(OH)_3$
C $(CH_3)_2Si(OH)_2$
D $(CH_3)_3SiOH$

T2-10 30 **C**

Under conditions when hydrolysis and subsequent condensation reactions could be expected to occur, the chlorosilane $(CH_3)_3SiCl$ will probably

A form the linear polymer $\{-(CH_3)_2Si-O-Si(CH_3)_2-O-\}_n$.
B form a cross linked silicone resin.
C form the dimer $(CH_3)_3Si-O-Si(CH_3)_3$.
D not react.

T2-11 40 **C**

The types of reaction occurring in the production of silicones from chlorosilanes are, in order,

A addition, condensation.
B substitution, addition.
C substitution, condensation.
D hydrolysis, addition.

T2-12 40 **A**

A silicone grease is best described as a

A linear polymer mixed with an inert filler.
B polymer containing cross links every 1 000 atoms.
C polymer containing cross links every 100 atoms.
D polymer in which every silicon atom participates in cross linking.

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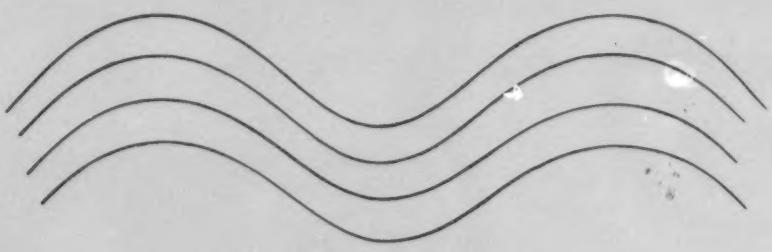
The next two items refer to the following information

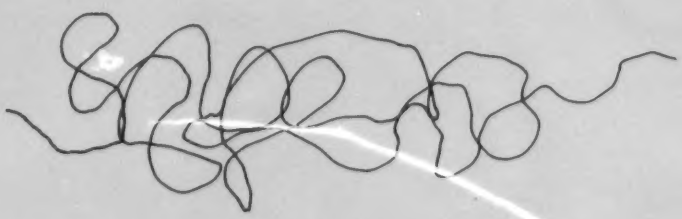
The diagrams below represent the structures of various types of polymers.

I

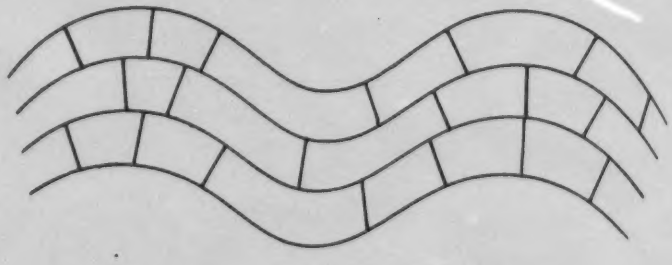


II

III



IV



T2-13 The structure of high density poly(ethene) is best represented by

60

A **A** I . **B** II . **C** III . **D** IV .

T2-14 The structure of a silicone resin is best represented by

70

D **A** I . **B** II . **C** III . **D** IV .

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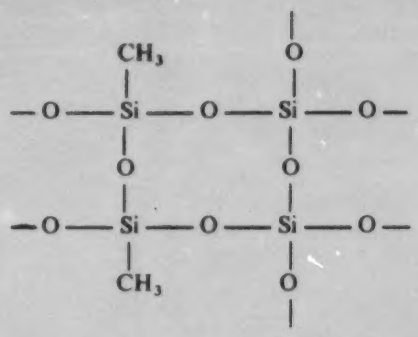
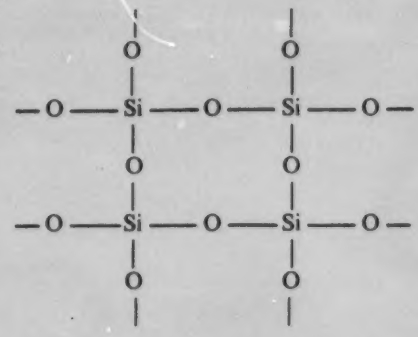
T2-15 50 **A**

Which one of the following formulae best represents the structure of a silicone sealant after prolonged exposure to the air?

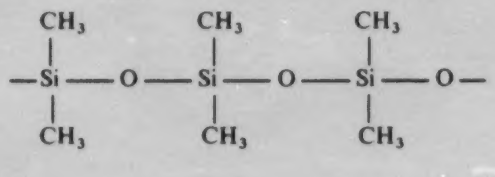
A



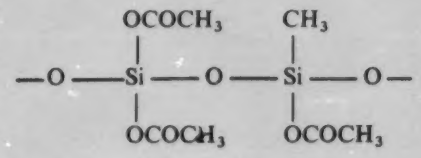
C



B



D



T2-16 60 **B**

The odour of acetic acid is detected during the hardening of the liquid from a tube of a common silicone sealant.

The liquid in the tube probably consists of a

A solution of a cross linked polymer in acetic acid.
B linear polymer with acetate side groups.
C polymer cross linked by acetate groups.
D solution of a cross linked polymer in water.

T3 Silicon carbide

T3-1 80 **B**

Which one of the following statements is consistent with the structure of silicon carbide?

A It is covalently bonded because it is formed by subjecting carbon and silicon to very high temperatures.
B It has strong covalent bonds in three dimensions.
C It is a layer lattice with each atom covalently bonded to three other atoms.
D Each carbon atom is covalently bonded to one other carbon atom.

T4 Silicon dioxide

T4a Occurrence

T4a-1 70 **A**

Which of the following materials is likely to contain the highest proportion of silica, SiO_2?

A quartz **B** clay **C** soda glass **D** limestone **E** ceramics

T4a-2 80 **C**

Which one of the following groups contains the formula of a substance which is unlikely to be found in large organisms?

A CO_2; O_2; $C_6H_{12}O_6$
B H_2O; CO_2; NaCl
C CO_2; NH_3; SiO_2
D O_2; $(NH_2)_2CO$; H_2O

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T4b Structure

T4b-1
70
B

Silica (SiO_2) occurs naturally in three crystalline forms.
Each of these forms

A has a crystal structure identical to each of the other forms.
B has the atoms arranged in a covalent network lattice.
C has physical properties identical to each of the other forms.
D has each silicon atom bonded to four oxygen atoms and vice versa.

T4b-2
80*
B

Silicon dioxide is used to line furnaces because it has a high melting temperature. Its resistance to heat is a consequence of

A a close packed structure of SiO_2 molecules with strong covalent bonds between atoms.
B a network lattice structure of Si and O atoms held together by strong covalent bonds.
C a lattice structure of Si^{4+} and O^{2-} ions held together by strong electrostatic attraction.
D a lattice of diatomic oxygen molecules strongly bonded to silicon atoms by electrostatic bonds.

T4b-3
40
A

Which of the following oxides differs most markedly in structure from the others?

A silicon dioxide **B** nitrogen dioxide **C** carbon dioxide **D** water

T4c Properties

T4c-1
30
D

Solid silicon dioxide is best described as

A a basic oxide with a discrete molecular structure.
B an acidic oxide with a discrete molecular structure.
C a basic oxide with a network lattice structure.
D an acidic oxide with a network lattice structure.

T4c-2
40
A

Which one of the following statements about the properties of silica is correct?
Silica is

A an acidic oxide which dissolves very slightly in water.
B an acidic oxide which is very soluble in water.
C a basic oxide which dissolves very slightly in water.
D a basic oxide which is very soluble in water.
E a neutral oxide which dissolves very slightly in water.

T4c-3
10
A

Which of the following oxides reacts to the greatest extent with hydroxide ions?

A SiO_2 **B** Na_2O_2 **C** NO **D** CO

T4c-4
30
A

Silica, SiO_2,

A reacts slowly and to a small extent with water to give $Si(OH)_4(aq)$ and with melted NaOH to give Na_2SiO_3.
B reacts slowly and to a small extent with water to give $Si(OH)_4(aq)$, but not with melted NaOH.
C reacts neither with water nor with melted NaOH.

T4c-5
30
D

Which one of the following statements about silica, SiO_2, is **incorrect?**
Silica

A melts above 1000 °C at atmospheric pressure.
B is a poor electrical conductor in the solid and liquid states.
C reacts more extensively with NaOH solutions than with pure water.
D acts as either an acidic or basic oxide.
E exists in a number of structural forms at room temperature.

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T5 Silicates

T5a Occurrence

T5a-1 | 70 | D

Which one of the following materials does **not** contain silicates?

A ceramics
B soda-glass
C Portland cement
D sea shells

T5b Glass

T5b-1 | 60 | A

Which of the following mixtures alone will provide the essential materials used to make most glass bottles?

A sand, sodium carbonate and limestone
B sodium carbonate and sand
C sand and limestone
D limestone, sand and carbon dioxide

T5b-2 | 50 | B

Which of the following is **not** a property of glass?

A Glass softens gradually over a range of temperatures.
B The brittleness of glass is independent of the rate of cooling.
C Glass crystallizes only slowly at room temperature.
D Solid glass shows some of the properties of a liquid.

T5b-3 | 60 | D

The glass that is usually used for window panes and bottles can be considered to be

A a crystalline mixture of silica and sodium silicate.
B a crystalline mixture of silica, sodium silicate and calcium silicate.
C a supercooled liquid mixture of silica and sodium silicate.
D a supercooled liquid mixture of silica, sodium silicate and calcium silicate.

T5b-4 | 40 | C

Vegetables are often snap-frozen by rapid cooling to -150 °C. This causes the water in the vegetables to form a glass. Water treated in this fashion is likely to have a

A more ordered structure than normal ice.
B melting temperature of 0 °C.
C higher density than normal ice.
D covalent network lattice structure.

T5b-5 | 50* | D

It is observed that glass window panes become thicker at the bottom than at the top over a long period of time. This occurs because

A glass at the top of the panes is dissolved by rain water and redeposited at the bottom as the water evaporates.
B the sun's radiation causes the outer layer of the glass to melt and slowly flow downwards.
C SO_2 and NO_2 gases dissolved in rain water tend to dissolve the exposed upper sections of the window panes.
D the glass behaves like a viscous fluid and slowly flows downwards.

T5b-6 | 30 | C

Chemists often avoid storing concentrated sodium hydroxide solution in glass bottles because

A hydroxide ions catalyse the formation of crystals in the supercooled liquid structure of glass.
B silicon dioxide dissolves slowly in the solution forming a white precipitate of silicic acid.
C silicon dioxide reacts with sodium hydroxide, forming a sodium silicate impurity in solution.
D the glass bottles become brittle as carbonate ions in the glass react slowly with hydroxide ions.

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T5c Clays, Ceramics, Portland cement

T5c-1
70
D

Clays are produced by

A the dissolving of silicate minerals in rain water.
B the weathering of sand grains containing silica.
C the reaction between silica-containing quartz and bicarbonate ion in the soil.
D the sticking together of small particles formed by the breakdown of silicate minerals.

T5c-2
80
C

Clays are the raw materials for many materials used in construction and fabrication, e.g. bricks for building, pipes for drainage, porcelain for household china, ornaments and insulators on power lines.

Which one of the following statements about clays is **not** true?

A They are essentially the weathered remains of various types of rocks.
B When moist, they are plastic. They become very rigid when dried but regain their plasticity when rewetted.
C Many economically important metals are extracted commercially from clays.
D When fired, clays become mechanically strong, hard, and permanently non-plastic due to a fusing together of the smaller particles.

T5c-3
60*
B,D

Clay is used extensively in the production of **one or more** of the following materials. Which one(s)?

A glass **B** cement **C** iron **D** ceramics

T5c-4
80
D

In the manufacture of ceramics, the reason for the high firing temperature of the clay is to

A soften the mixture as a preparation for pouring into moulds.
B drive off the water of crystallization in order to increase the strength of the ionic bonding.
C increase the rate of particle diffusion, to ensure a regular crystal lattice.
D enable the particles present to fuse together to form a solid, coherent mass.

T5c-5
20
A,B,D

Which one (or more) of the following properties is (are) important in the use of clays for the manufacture of ceramics?

A When heated strongly, the particles fuse together, forming a hard non-plastic product.
B Strong heating results in a molecular rearrangement within the particles, resulting in a shiny appearance.
C When moist, clays have plastic properties.
D When dried, clays become rigid.

T5c-6
30*
D

When Portland cement is mixed with water and the paste is allowed to set it forms a stonelike material that is used extensively in the building industry.

Portland cement is made by heating together

A limestone, clay and sodium carbonate.
B sand and clay.
C clay, coke and limestone.
D limestone and clay.
E coke, sand and sodium carbonate.

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U NITROGEN CHEMISTRY

U1 The element

U1a Occurrence

U1a-1 70 **A**

The majority of nitrogen found on earth is present as

A N_2. **B** NO_3^-. **C** NH_3. **D** NO_2. **E** protein.

U1a-2 80 **B**

One or more of the following substances does **not** contain nitrogen. Which one(s)?

A enzymes **B** starch **C** proteins **D** DNA

U1a-3 20 **D**

The most concentrated deposits of nitrogen compounds are found in areas with

A high thunderstorm activity.
B nearby volcanic activity.
C dense plant growth.
D low rainfall.

U1a-4 30 **B**

Before the first world war nitrogen containing compounds used in explosives were obtained from deposits in Chile. Such concentrated deposits are rarely found on the earth's surface. This is **mainly** because

A nitrogen is a relatively unreactive element and tends to exist as N_2 gas.
B nitrogen compounds are usually soluble in water.
C nitrogen preferentially forms organic compounds rather than inorganic compounds.
D the conditions required to produce these compounds are too extreme to occur naturally.

U1b Production

U1b-1 70 **D**

The majority of the pure nitrogen used in industry is obtained by

A combustion of NH_3 in pure oxygen.
B heating NH_4NO_3 to 800 °C in the absence of air.
C removal of oxygen from clean air by combustion of magnesium.
D fractional distillation of liquid air.

U1b-2 50 **A**

A sealed vessel contains nitrogen gas at room temperature and high pressure. If the gas is released through a small aperture in the vessel into a thermally insulated container, then the temperature of the released gas will

A decrease.
B increase.
C increase and then decrease.
D remain unchanged.

U1b-3 30 **D**

A volume of air is cooled to 25 K and then returned to room temperature. As the temperature of the sample increases, the elements nitrogen, oxygen and neon will be distilled in the order

A oxygen, nitrogen, neon.
B nitrogen, oxygen, neon.
C nitrogen, neon, oxygen.
D neon, nitrogen, oxygen.
E neon, oxygen, nitrogen.

U1c Properties

U1c-1 50 **C**

Which of the following diatomic molecules has the greatest bond strength?

A HF **B** O_2 **C** N_2 **D** F_2

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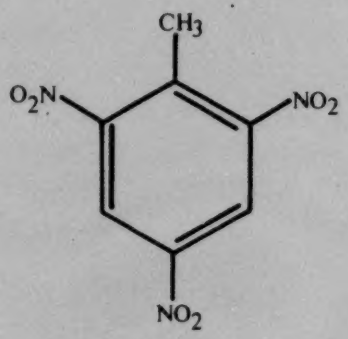
U1c-2
40
C

Molecular nitrogen is one of the most stable substances known. Which of the following facts **cannot** be directly related to the high stability of nitrogen molecules?

A Many nitrogen compounds are highly explosive.
B Ammonia burns in oxygen, producing nitrogen and water.
C The boiling temperature of nitrogen is lower than that of oxygen.
D Nitrogen compounds are less abundant in the earth's crust than carbon or oxygen compounds.

U1c-3
30
C

The explosive trinitrotoluene (TNT) has the structure



One of the major reasons for its explosive properties is that the

A benzene ring is unsaturated and is easily attacked by oxygen at high temperatures.
B NO_2 groups can be readily oxidized to NO_3^- ions.
C N_2 formed as a reaction product has a very high bond strength.
D molecule readily decomposes to form toluene and NO_2 gas.

U1c-4
10
C

Which **one or more** of the following statements describe(s) a role of atmospheric nitrogen?

A It is the immediate source of the nitrates required by plants.
B It is oxidised to NO_2 at the temperature of a lightning flash.
C It prevents excessive rates of combustion in systems exposed to the atmosphere.
D It is converted to HNO_3 and NH_3 at the temperature of a lightning flash.

U2 Ammonia

U2a Structure

U2a-1
40
C

The atoms in a molecule of ammonia are arranged in a

A tetrahedron. **B** trigonal plane. **C** pyramid. **D** V-shape.

U2b Preparation

U2b-1
30
C

Which of the following pairs of substances could provide a convenient source of ammonia gas for laboratory use when heated together over a Bunsen flame?

A nitrogen and hydrogen
B nitrogen and sulfuric acid
C ammonium chloride and calcium hydroxide
D ammonium chloride and sulfuric acid

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The next two items refer to the following information

Ammonium chloride, NH_4Cl, decomposes on heating according to the following reaction:

$$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$$

U2b-2
60
C

A method for the laboratory preparation of gaseous NH_3 is required.
The heating of NH_4Cl is **not** suitable since

A NH_4Cl is sufficiently stable to heat to resist decomposition, except at very high temperatures.
B NH_4Cl is explosively unstable on heating.
C the NH_4Cl decomposes readily, but the NH_3 and HCl formed recombine on cooling.
D NH_4Cl does not decompose unless it is dissolved in water. The water however would dissolve the NH_3 produced.

U2b-3
40
B

The heating of NH_4Cl could be used as a suitable method for preparing gaseous NH_3 if the following modification were used:

A After heating, cool the products rapidly to prevent their recombination.
B Heat the NH_4Cl with a base such as $Ca(OH)_2$ to remove the HCl.
C Heat the NH_4Cl with an acid such as H_2SO_4. Since H_2SO_4 is the stronger acid, the HCl will be displaced, leaving NH_3.
D Heat NH_4Cl with a suitable reductant to convert the NH_4^+ to NH_3.

U2b-4
50
D

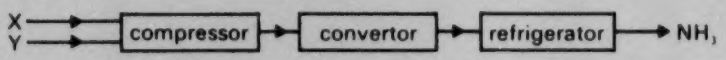
The commercial production of ammonia is represented by the equation

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The reaction conditions may be adjusted so that

A increasing the temperature allows the forward reaction to proceed to a greater extent.
B lowering the pressure allows the forward reaction to proceed to a greater extent.
C any change in the rate of the forward reaction is compensated by an equal change to the rate of the back reaction.
D the rate of the forward reaction is fast enough to partially compensate for its small extent.

The next two items refer to the flow diagram below for the Haber Process.



U2b-5
90
B

The gases X and Y are

A air and hydrogen.
B hydrogen and nitrogen.
C air and nitrogen.
D nitrogen and steam.

U2b-6
80
C

In the compressor, the pressure of the incoming gases is increased in order to

A facilitate the dissociation of reactant molecules.
B increase the yield of ammonia being formed in the compressor.
C force the equilibrium position to the right for the reaction in the converter.
D eliminate the need for a catalyst.

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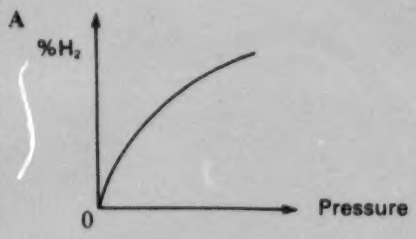
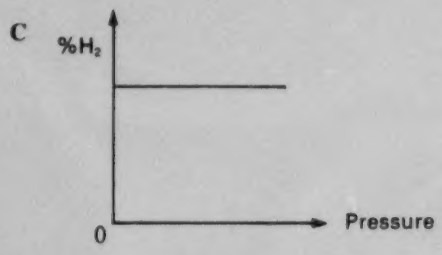
U2b-7
50
B

A vessel containing H_2, N_2 and NH_3 is maintained at a constant temperature of 300 °C. Which of the following graphs best represents the relationship between the equilibrium percentage of H_2 present in the vessel as the total pressure of the vessel varies?

A



C



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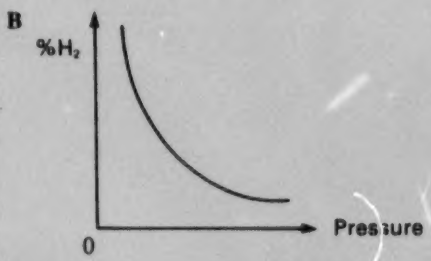

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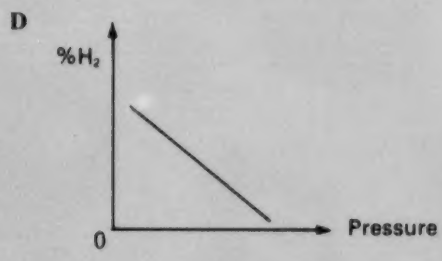


U2b-8
80
B

The preparation of ammonia from its elements is an exothermic process. Conditions to obtain a favourable equilibrium yield in this reaction would be

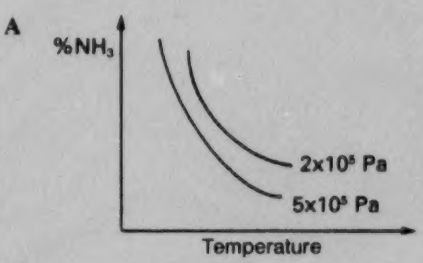
A high temperatures and high pressures.
B low temperatures and high pressures.
C low temperatures and low pressures.
D high temperatures and low pressures.

U2b-9
50
C

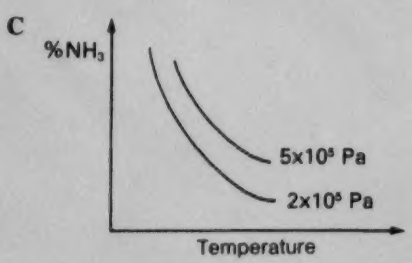
The reaction between N_2 and H_2 to produce NH_3 is exothermic. The fraction of NH_3 present in an equilibrium mixture of the gases is dependent upon temperature and pressure.

Which of the following graphs best represents the variation of the equilibrium fraction of NH_3 with temperature at pressures of 2×10^5 Pa and 5×10^5 Pa?

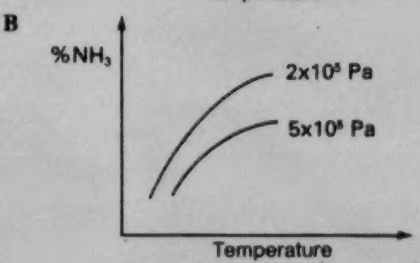
A



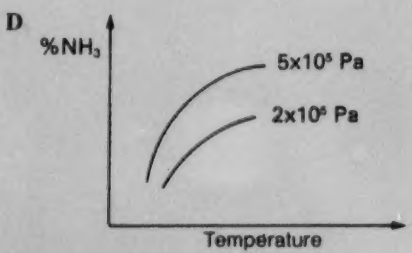
C



B



D



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U2c-1
80
B

A gas has the following properties: it is colourless, highly soluble in water, and will change damp litmus paper from red to blue.

Of the following, the gas is

A hydrogen chloride (HCl).
B ammonia (NH_3).
C sulfur trioxide (SO_3).
D nitrogen oxide (NO).

U2c-2
60
B

Ammonia has a boiling temperature of −33 °C.

The boiling temperature of phosphine (PH_3) will be

A higher than −33 °C, because phosphine molecules contain more electrons than ammonia molecules.
B lower than −33 °C, because the bond polarity in phosphine is much less than that in ammonia.
C higher than −33 °C, because the hydrogen bonds between phosphine molecules are stronger than those between ammonia molecules.
D lower than −33 °C, because P–H bonds are stronger than N–H bonds.

U2c-3
50
B

Ammonia, NH_3, has a considerably higher boiling temperature than phosphine, PH_3. This fact is best explained as being due to

A stronger dispersion forces between NH_3 molecules than between PH_3 molecules.
B stronger dipolar bonding forces between NH_3 molecules than between PH_3 molecules.
C N-H covalent bonds being stronger than P-H covalent bonds.
D PH_3 being a stronger base than NH_3.

U2c-4
60
E

Equal volumes of the following gases were shaken with water. Which gas would cause the greatest increase in the pH?

A CO_2 B NO_2 C CO D CH_4 E NH_3

U2c-5
20
A

Which of the species below is most abundant in an aqueous solution of ammonia?

A NH_3 B NH_4^+ C OH^- D H_3O^+

U2c-6
60
C

A deep blue solution can be formed by adding concentrated ammonia solution to a solution containing Cu^{2+} ions. The deep blue colour is due to

A reduction of Cu^{2+} by ammonia to Cu^+.
B formation of a complex ion containing Cu^{2+} and NH_4^+.
C formation of the species $Cu(NH_3)_4^{2+}$.
D reaction of Cu^{2+} ions with the base to produce $Cu(OH)_2$.

U2c-7
80
D

If a saturated solution of copper hydroxide in equilibrium with excess solid was maintained at a constant temperature, which of the following would cause additional copper hydroxide to dissolve?

A evaporation of half the water
B addition of solid $Cu(OH)_2$
C addition of solid NaOH
D addition of NH_3 solution

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The next two items refer to the following information

A saturated solution of copper(II) hydroxide is in equilibrium with excess solid.

U2c-8 30 **D**

The amount of solid copper(II) hydroxide present can be **increased** by

A addition of concentrated ammonia solution.
B raising the temperature of the solution.
C addition of 2 M sulfuric acid.
D addition of 2 M sodium hydroxide solution.

U2c-9 30 **B**

The concentration of the species $Cu^{2+}(aq)$ in solution can be **increased** by

A addition of concentrated ammonia solution.
B addition of 2 M sulfuric acid.
C addition of a large volume of water.
D reducing the temperature.

U2c-10 60 **D**

Silver chloride is virtually insoluble in water, yet significant amounts dissolve in 2 M ammonia solution.

The principle reaction involved in the dissolution of AgCl is

A the reaction of NH_4^+ ions with Cl^- ions to form soluble NH_4Cl.
B the removal of Ag^+ ions from solution as $Ag(OH)_2^-$ complex ions.
C the reaction of Ag^+ ions with OH^- ions to form soluble AgOH.
D the removal of Ag^+ ions from solution as $Ag(NH_3)_2^+$ complex ions.

U2c-11 50 **C**

Silver chloride reacts with an aqueous ammonia solution.

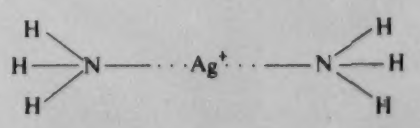
The equation which best describes this reaction is

A $AgCl(s) + 2NH_3(aq) \rightarrow NH_4Cl(aq) + AgNH_2(s)$
B $AgCl(s) + NH_3(aq) \rightarrow HCl(aq) + AgNH_2(s)$
C $AgCl(s) + 2NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + Cl^-(aq)$
D $AgCl(s) + 2NH_3(aq) + 2H_2O(l) \rightarrow Ag(NH_4)_2^{3+}(aq) + Cl^-(aq) + 2OH^-(aq)$

U2c-12 70 **A**

Which of the structural formulae below best represents the complex ion formed between Ag^+ ions and NH_3 molecules?

A



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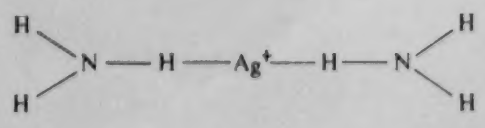
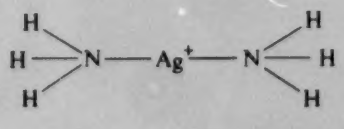
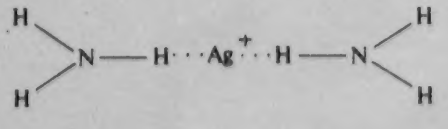


B



D



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U2c-13
20
C

Which of the following compounds would be **least** soluble in concentrated ammonia solution?

A $Cu(OH)_2$ B $AgCl$ C $Fe(OH)_3$ D $Ni(OH)_2$

U2c-14
50
C

Which one of the following expressions will have the lowest equilibrium constant at room temperature and atmospheric pressure?

A $NH_3(g) + aq \rightleftharpoons NH_3(aq)$

B $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

C $NH_3(aq) + H_2O(l) \rightleftharpoons NH_2^-(aq) + H_3O^+(aq)$

D $Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq)$

U2c-15
40
B

Hydrogen bonding plays a significant role in determining the properties of all of the following substances **except** one. Which one?

A liquid ethanoic (acetic) acid
B solid ammonium chloride
C liquid hydrogen peroxide
D liquid ammonia

U2c-16
40
C

Which of the following is **not** a consequence of hydrogen bonding?

A solubility of ethanol in water
B helical structure of DNA
C tetrahedral shape of NH_4^+
D relative boiling points of NH_3 and PH_3

U3 Nitrogen oxides

U3a Occurrence

U3a-1
40
E

Photochemical smog arises from the action of sunlight on mixtures of

A SO_2, hydrocarbons and O_3.
B NO_x, CO and O_3.
C SO_2, hydrocarbons and O_2.
D NO_x, SO_2, CO and O_3.
E NO_x, hydrocarbons and O_2.

U3a-2
40
B

Some chemicals produced by the internal combustion engine are a major source of pollution. These chemicals include

A NO_2 produced by the reaction of atmospheric nitrogen with oxygen at high temperatures.
B NO produced by the reaction of atmospheric nitrogen with oxygen at high temperatures.
C NO_2 produced by the reaction of nitrogen impurities in the fuel with oxygen at high temperatures.
D NO produced by the reaction of nitrogen impurities in the fuel with oxygen at high temperatures.

U3a-3
80
A

Which one of the following reaction sequences best summarizes the production of the main nitrogen oxide pollutants by the internal combustion engine?

A $N_2 + O_2 \xrightarrow[\text{chamber}]{\text{in combustion}} NO \xrightarrow[\text{in air}]{O_2} NO_2$

B $N_2 + O_2 \xrightarrow[\text{chamber}]{\text{in combustion}} NO_2 \xrightarrow[\text{in air}]{N_2} NO$

C $NO + O_2 \xrightarrow[\text{chamber}]{\text{in combustion}} NO_2 \xrightarrow[\text{in air}]{N_2} NO$

D $NO_2 + N_2 \xrightarrow[\text{chamber}]{\text{in combustion}} NO \xrightarrow[\text{in air}]{O_2} NO_2$

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U3a-4 70 C

If a car engine was tuned to admit more air into the combustion chambers, then which of the following changes in the composition of the exhaust gases would be expected?

A NO_x emissions would be halted.
B The amount of unburnt hydrocarbon would increase.
C The amount of CO_2 would increase.
D The amount of CO would increase.

U3a-5 20 B

Which of the following is likely to be most abundant in the exhaust gases from a car engine?

A NO **B** H_2O **C** CO **D** NO_2

U3a-6 20 A

In car engines nitrogen reacts with oxygen forming nitrogen oxide, according to the equation

$$N_2 + O_2 \rightleftharpoons 2NO$$

It might be expected that as the temperature of the exhaust gases decreases most of the nitrogen oxide would decompose back to its elements. This is not observed because

A the rate of decomposition of NO is slow at lower temperatures.
B the high concentration of nitrogen and oxygen in the atmosphere favours the forward reaction.
C NO rapidly reacts with unburnt hydrocarbons, producing photochemical smog.
D the equilibrium constant for the reaction increases as the temperature decreases.

U3b Preparation

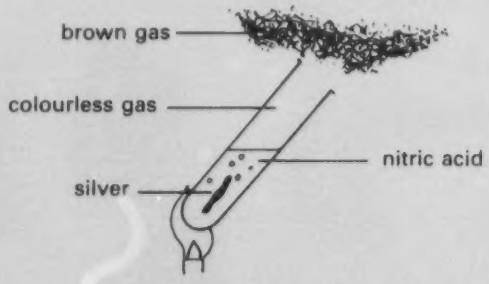
U3b-1 70 B

Addition of metals such as silver, copper and zinc to concentrated (14 M) nitric acid causes the acid to be reduced to

A NO. **B** NO_2. **C** N_2O. **D** N_2O_3.

U3b-2 40 B

The result of adding a strip of silver to a test tube containing nitric acid is represented in the diagram below.



The colourless gas observed in the test tube is mainly

A N_2O_4. **B** NO. **C** H_2. **D** NO_2.

U3b-3 70 D

Nitrogen oxide, NO, can be prepared for use in the laboratory by

A passing NO_2 gas through a potassium permanganate solution.
B heating ammonium nitrate to 200 °C.
C heating an equimolar mixture of nitrogen and oxygen to 200 °C.
D adding copper to 7 M nitric acid.

U3b-4 40 D

Nitrogen dioxide, NO_2, is usually prepared in the laboratory by

A heating a mixture of nitrogen and oxygen to 150 °C.
B heating ammonium nitrate to 200 °C.
C heating copper in 7 M nitric acid.
D adding copper to concentrated (14 M) nitric acid.

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U3b-5
30
C

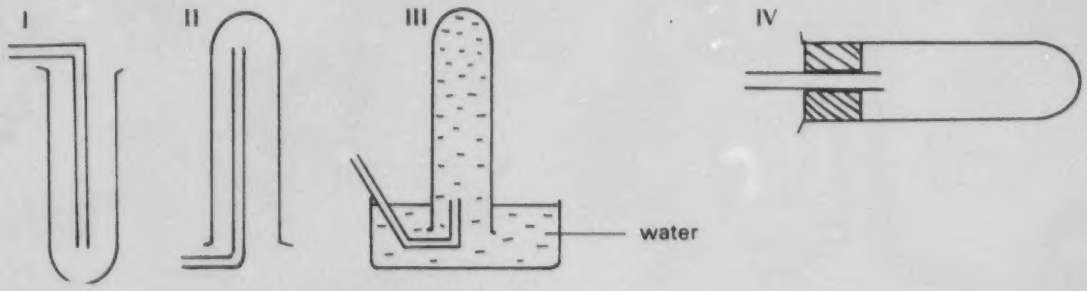
In which of the following reactions is the total energy of the products greater than the total energy of the reactants at the same temperature?

A $N_2 + 3H_2 \rightleftharpoons 2NH_3$
B $SO_2 + \frac{1}{2}O_2 \rightleftharpoons SO_3$
C $N_2 + O_2 \rightleftharpoons 2NO$
D $4NH_3 + 5O_2 \rightleftharpoons 4NO + 6H_2O$

U3c Properties

The next two items refer to the following information

The diagram below represents apparatus which might be used for the collection of gases.



U3c-1
40
C

Of the four methods illustrated, the most appropriate method for collecting NO gas is

A I. B II. C III. D IV.

U3c-2
30
A

Of the four methods illustrated, the most appropriate method for collecting NO_2 gas is

A I. B II. C III. D IV.

U3c-3
70
B

A student claimed that he had prepared a jar containing only NO_2 gas in his school laboratory, by reacting copper with concentrated nitric acid at room temperature.

His claim is likely to be **incorrect** because

A NO_2 is completely converted to NO at room temperature.
B NO_2 exists in an equilibrium mixture with N_2O_4, with the latter predominating at room temperature.
C NO_2 is present in an equilibrium mixture with NO, with the latter predominating at room temperature.
D NO_2 exists in an equilibrium mixture with N_2O, with the latter predominating at room temperature.

U3c-4
60
B

A gas syringe contains an equilibrium mixture of NO_2 and N_2O_4. When the plunger of the syringe is suddenly drawn out, which of the following occurs?

A all concentrations decrease immediately, then the concentration of NO_2 decreases further while that of N_2O_4 increases
B all concentrations decrease immediately, then the concentration of NO_2 increases while that of N_2O_4 decreases further
C all concentrations decrease immediately, then subsequently decrease further
D all concentrations decrease immediately, then subsequently increase

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U3c-5
60*
C

Descriptions of the odour of NO gas are usually omitted from lists of its properties. This is because NO

A reacts rapidly with water in the nose or mouth forming nitrous acid.
B is extremely poisonous in concentrations at which its odour is undetectable.
C reacts with oxygen at room temperature forming nitrogen dioxide.
D is a highly stable molecule and therefore does not have a detectable odour.

U3c-6
30
D

A mixture of NO, NO_2 and O_2 was allowed to reach equilibrium, according to the equation

$$2NO + O_2 \rightleftharpoons 2NO_2 \qquad \Delta H = -181 \text{ kJ mol}^{-1}$$

If the temperature and pressure of the system were increased, the amount of NO present when equilibrium is re-established would be

A increased.
B decreased.
C unchanged.
D unable to be predicted.

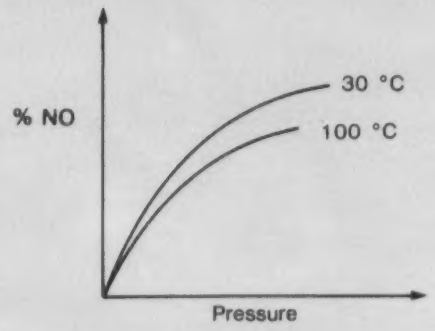
U3c-7
30
D

A system containing NO_2, NO and O_2 is at equilibrium, according to the equation

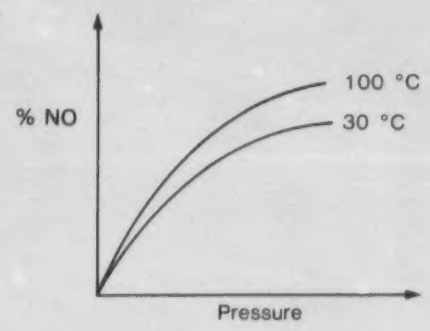
$$2NO + O_2 \rightleftharpoons 2NO_2 \qquad \Delta H = -181 \text{ kJ mol}^{-1}$$

Which of the following graphs best portrays the relationship between the percentage of NO in the equilibrium system and the total pressure of the system at temperatures of 30 °C and 100 °C?

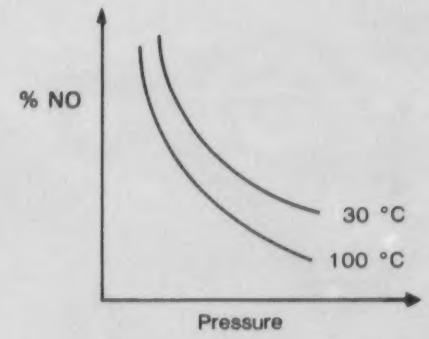
A



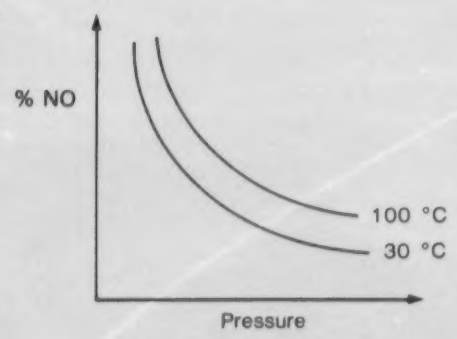
C



B



D



U3c-8
70
B

Which one of the following substances dissolves in water to produce an acidic solution?

A CO **B** NO_2 **C** Na_2O **D** $CaCO_3$

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U3c-9
70
A

Which one of the following oxides does not react with water to form an acidic solution?

A N_2O **B** N_2O_3 **C** N_2O_5 **D** P_4O_6 **E** P_4O_{10}

U3c-10
40
B

Which one of the following oxides does **not** react with a concentrated solution of sodium hydroxide?

A P_4O_{10} **B** NO **C** SO_3 **D** CO_2 **E** SO_2

U3c-11
60
B

The acid anhydride of nitrous acid is

A N_2O. **B** N_2O_3. **C** N_2O_5. **D** HNO_3.

U3c-12
40
C

A pure sample of a gaseous oxide of nitrogen reacts with aqueous sodium hydroxide to form an equimolar mixture of sodium nitrate and sodium nitrite. The gas is

A NO. **B** N_2O. **C** NO_2. **D** NO_3.

U3c-13
20
D

A mixture of NO and NO_2 gas may be obtained when copper is added to nitric acid of a suitable concentration at 20 °C.

Which of the following operations is most likely to increase the proportion of NO in such a mixture of gases?

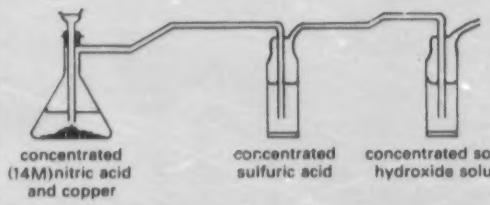
A add a small amount of oxygen gas
B cool the gases to 10 °C
C add a small amount of nitrogen gas
D shake with a small quantity of water

U3c-14
20*
D

The reaction between nitric acid and copper turnings can be used in the laboratory to produce nitrogen oxide gas, NO. The gas which is obtained may be contaminated by nitrogen dioxide, NO_2.

Which of the following sets of apparatus would be best to use for the production of pure, **dry** nitrogen oxide?

A



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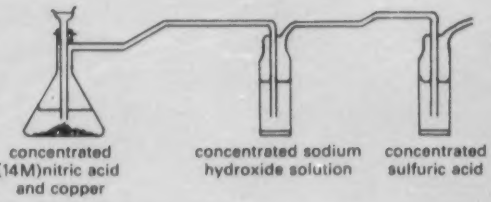

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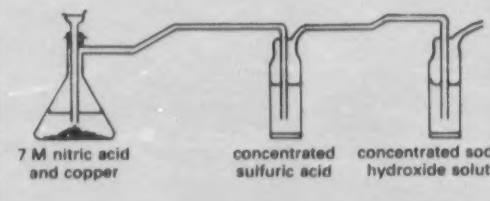
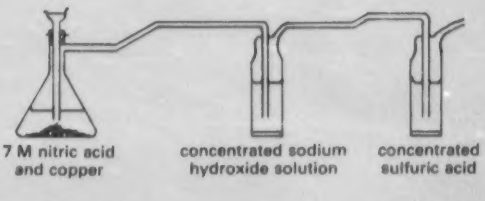


D



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U3c-15
40
A

Which of the following species will be present in the greatest concentration when NO_2 is bubbled through cold water?

A $H_3O^+(aq)$ **B** $HNO_2(aq)$ **C** $NO_3^-(aq)$ **D** $HNO_3(aq)$

U3c-16
60
A

Nitrogen dioxide dissolves in water to form a mixture of nitric and nitrous acids, as shown by the equation

$$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2.$$

This reaction is an example of

A a redox reaction.
B an acid-base reaction.
C a substitution reaction.
D a condensation reaction.

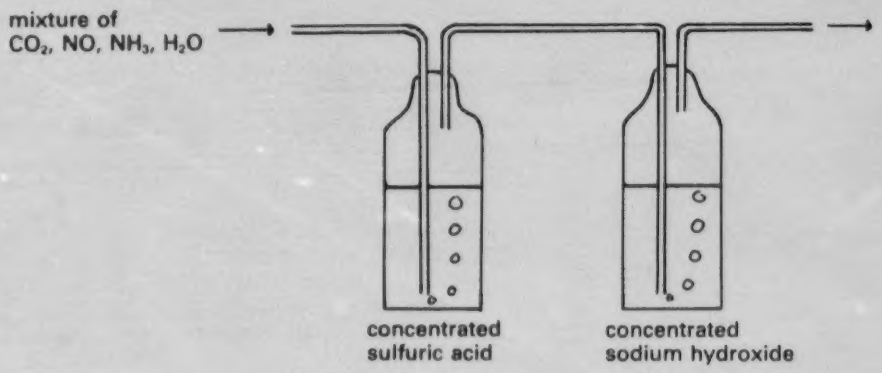
U3c-17
50
C

The oxide NO_2 and its dimer N_2O_4 are acidic oxides. In which of the following situations is this property **not** relevant?

A HNO_3 is produced commercially from NO_2.
B The presence of NO_2 in moist air after an electrical storm leads to the presence of some nitrate ions in rain.
C N_2O_4 is used in rocket propulsion systems.
D $NaNO_2$ and $NaNO_3$ are formed by the reaction of NO_2 with NaOH solution.

The next two items refer to the following information

A gaseous mixture of carbon dioxide, nitrogen oxide, ammonia and water vapour is passed through concentrated sulfuric acid and then through concentrated sodium hydroxide solution, as shown.



U3c-18
40
A,B

Which **one or more** of the following would be present in the gas after passage through the sulfuric acid?

A carbon dioxide **B** nitrogen oxide **C** ammonia **D** water vapour

U3c-19
10
B,D

Which **one or more** of the following would be present in the gas after it passes through the sodium hydroxide solution?

A carbon dioxide **B** nitrogen oxide **C** ammonia **D** water vapour

U3c-20
30
C

A chemist wishes to isolate pure dry carbon monoxide from a mixture of 1 mol of CO, 1 mol of NH_3 and 1 mol of NO using the following operations:

I passing the mixture through concentrated sodium hydroxide solution
II passing the mixture through concentrated sulfuric acid
III adding 0.5 mol of O_2 to the mixture

The order in which the chemist should perform these operations would be

A II, I, III.
B II, III, I.
C III, I, II.
D III, II, I.

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U4 Nitric acid

U4a Preparation

U4a-1 60 **A**

Industrially-prepared nitric acid (HNO_3) is usually made from

A NO prepared by oxidizing NH_3.
B NO prepared by treating Cu with HNO_3.
C NO_2 prepared by reacting N_2 with O_2.
D NO prepared by reacting N_2 with O_2.

U4a-2 70 **B**

The Ostwald preparation of nitric acid involves a number of reactions. Which of the reaction sequences below summarizes part of this process?

A $N_2 \xrightarrow{O_2} NO_2 \xrightarrow{N_2} NO$
B $NH_3 \xrightarrow{O_2} NO \xrightarrow{O_2} NO_2$
C $NH_3 \xrightarrow{O_2} NO_2 \xrightarrow{N_2} NO$
D $N_2 \xrightarrow{O_2} NO \xrightarrow{O_2} NO_2$

U4a-3 40 **C**

Which **one or more** of the following statements concerning the Ostwald Process is **incorrect**?

A The production of nitric acid from ammonia involves a process of oxidation.
B The conversion of ammonia to nitrogen oxide requires a catalyst.
C Nitrogen oxide is heated to a high temperature to speed up its conversion to nitrogen dioxide.
D The reaction of nitrogen dioxide with water produces a mixture of nitrous and nitric acids.

U4a-4 40 **C**

In the Ostwald process, nitric acid is produced by hydrolysis of dinitrogen tetroxide, according to the equation

$$N_2O_4 + H_2O \rightarrow HNO_3 + HNO_2$$

The nitrous acid that is also formed in this reaction is not a major impurity because

A it is rapidly oxidized by N_2O_4 to nitric acid.
B it exists as a gas at the temperatures at which the reaction is performed.
C it is unstable and decomposes into NO, NO_2 and water.
D it is readily removed by passing the hydrolysis products through aqueous NaOH solution.

U4a-5 40 **C**

Nitric acid production from ammonia is a multi-step operation, in which the reaction conditions are carefully chosen.

A condition which would **not** lead to a high yield of nitric acid involves

A the use of a catalyst to favour the production of NO, and not N_2, from the combustion of NH_3.
B a temperature sufficiently high to result in a high yield of NO, but not high enough to cause breakdown of NO to N_2 and O_2.
C a temperature sufficiently high to prevent N_2O_4 production from the oxidation of NO.
D the decomposition of any HNO_2 produced to NO and NO_2 which can be re-oxidised.

U4b Properties

U4b-1 30 **B**

Nitric acid can act as a powerful oxidizing agent. Which of the following substances is least likely to be produced when nitric acid oxidizes a metal?

A NH_4^+ **B** N_2O_5 **C** N_2O_4 **D** HNO_2

U4b-2 20 **D**

Which of the following compounds would be **least** efficient as a dehydrating agent?

A CaO **B** H_2SO_4 **C** P_4O_{10} **D** HNO_2

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U5 The nitrogen cycle

U5-1 70 **A**

In which of the following ways do most plants obtain the nitrogen they require for their metabolic processes?

A by taking up nitrate ions from the soil, through the roots
B by taking up ammonium ions, produced by denitrifying bacteria, through the roots
C by absorbing, through the roots, amino acids from the remains of dead organisms
D by absorbing nitrogen directly from the atmosphere

The next two items refer to the following information

Part of the nitrogen cycle can be represented in the following way

$$\begin{array}{ccc} N_2 & \rightarrow & NO \\ \uparrow & & \downarrow \\ NO_3^- & \leftarrow & NO_2 \end{array}$$

U5-2 20 **A**

Which one of the following phenomena could *not* be involved in this part of the cycle?

A the action of nitrogen fixing bacteria
B high temperature combustion
C electrical discharge
D the action of denitrifying bacteria

U5-3 90 **C**

Which of the following lists all the oxidation states shown by nitrogen in this part of the nitrogen cycle?

A $-3;\ 0;\ +1;\ +3$
B $-3;\ +1;\ +2;\ +3$
C $0;\ +2;\ +4;\ +5$
D $0;\ +3;\ +4;\ +5$

U5-4 20 **D**

Atmospheric fixation of nitrogen occurs in lightning flashes according to the equation

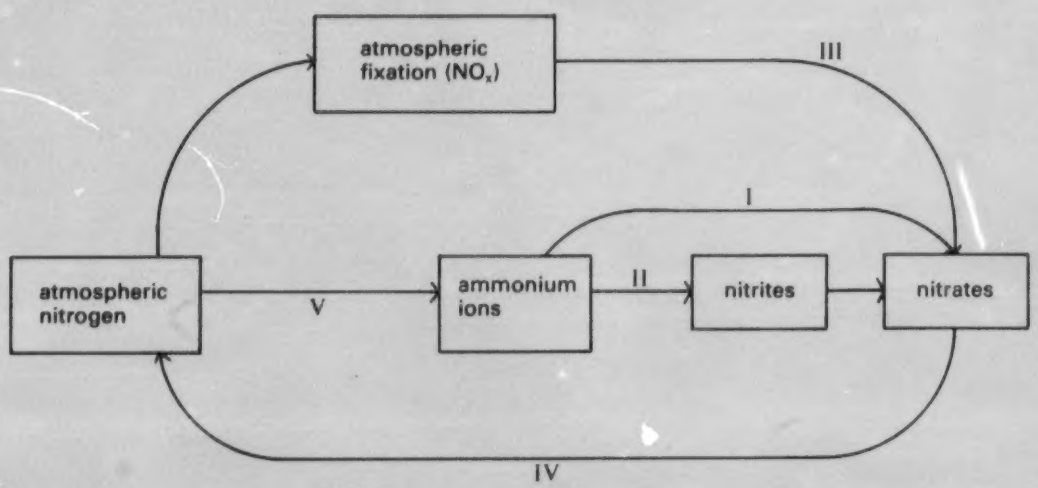
$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

For this reaction $K = 10^{-31}$ at 25 °C, and 5×10^{-3} at 3000 °C.
The differing K values indicate that

A the rate of NO formation is much greater at 3000 °C than at 25 °C.
B there will be a greater ratio of reactants to products at 3000 °C than at 25 °C.
C the reaction is exothermic.
D the decomposition of NO gives products with a heat content less than that of NO.

The next three items refer to the following information

A continuous exchange occurs between atmospheric nitrogen and the nitrogen in living things. This is represented in the following diagram.



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141

U5-5
50
B

An oxidation state which is not exhibited by atoms in the nitrogen species in the diagram above is

A −3. B −1. C +3. D +5.

U5-6
30
D

Ammonium ions are converted to nitrate ions in process I in the diagram by the action of

A dissolved oxygen in rain water.
B denitrifying bacteria in swampy areas.
C nitrogen fixing bacteria in the root nodules of legumes.
D nitrifying bacteria in the soil.

U5-7
50
C

Denitrifying bacteria are responsible for the reactions involved in process

A II. B III. C IV. D V.

U5-8
30*
A

Some of the reactions involved in the cycling of nitrogen from the air to living creatures are performed by bacteria. Nitrogen fixing bacteria are responsible for the conversion of

A N_2 to NH_3.
B N_2 to NO.
C NO_3^- to NO_2^-.
D NO_3^- to N_2.
E NO_2 to NO_3^-.

U5-9
50
A

The reaction between glucose and potassium nitrate,

$$C_6H_{12}O_6 + \tfrac{24}{5}\,KNO_3 \rightarrow 6CO_2 + \tfrac{18}{5}\,H_2O + \tfrac{24}{5}\,KOH + \tfrac{12}{5}\,N_2$$

is typical of reactions performed in the absence of oxygen by

A denitrifying bacteria.
B nitrogen-oxidizing bacteria.
C nitrifying bacteria.
D nitrogen fixing bacteria.

U5-10
40
C

In the absence of oxygen, one type of bacteria found in the earth uses reactions between NO_3^- or NO_2^- ions and organic compounds as a source of energy. A product from such reactions is

A NH_3. B NO. C N_2. D NH_4^+.

U5-11
50
A

Nitrifying bacteria are responsible for the conversion of

A NH_4^+ to NO_3^-.
B NO_3^- to N_2.
C N_2 to NO.
D NO to NO_2.

U5-12
70
A

Ammonium sulfate is used as a fertiliser because

A it acts as a source of NH_4^+ ions which can be used by plants as a source of nitrogen for amino acids.
B it aids in the eutrophication of soils.
C the NH_4^+ ions are easily oxidised to NO_3^- for incorporation into cellulose.
D it hydrolyses within the plant to provide a source of H_3O^+ ions for amino acid production.

U5-13
50
B

After placing large amounts of fertilizer on a paddock, a farmer was surprised to find that the fish in an adjacent pond were dying.

The best explanation of this phenomenon is that

A the fertilizers act as a poison on fresh-water animals.
B the resulting rapid growth of fresh-water plants has removed most of the available oxygen from the pond.
C the subsequent growth of fresh-water plants has removed all the available minerals from the pond.
D the accumulation of nitrogenous compounds in solution renders the pond unfit for animal life.

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U6 Amines

U6a Preparation

U6a-1 20 **A**

Ethanamine is best prepared from the reaction of ammonia and

A chloroethane, followed by addition of a strong base.
B ethane, in the presence of ultraviolet light.
C ethane, in the presence of a platinum catalyst.
D ethanol, followed by addition of a strong acid.

U6a-2 40 **B**

The compound $CH_3CH_2CH_2NH_2$ is produced when ammonia reacts with

A 1-propanol.
B 1-chloropropane.
C propanoic acid.
D propanal.
E propanone.

U6a-3 40 **C**

Primary amines have been identified in the brine in cans of tinned fish. A common method for preparing a primary amine in the laboratory is to react

A an alcohol with ammonia.
B an amide with concentrated acid.
C a chloroalkane with ammonia.
D an alcohol with an amide.

U6a-4 40 **B**

Which of the following reaction schemes outlines the best method of obtaining ethanamine from ethanol?

A $CH_3CH_2OH \xrightarrow{NH_3} CH_3CH_2NH_2$

B $CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl \xrightarrow{NH_3} CH_3CH_2NH_2$

C $CH_3CH_2OH \xrightarrow{H^+,\ Cr_2O_7^{2-}} CH_3CHO \xrightarrow{NH_3} CH_3CH_2NH_2$

D $CH_3CH_2OH \xrightarrow{H^+,\ Cr_2O_7^{2-}} CH_3COOH \xrightarrow{NH_3} CH_3CH_2NH_2$

U6b Properties

U6b-1 20 **D**

Which of the following organic compounds would act as the strongest base in water?

A CH_3CH_2Cl **B** CH_3CH_2OH **C** CH_3COOH **D** $CH_3CH_2NH_2$

U6b-2 50 **A**

Which one of the following substances is the most basic?

A aniline **B** glycerol **C** benzene **D** glycol

U6b-3 40* **B**

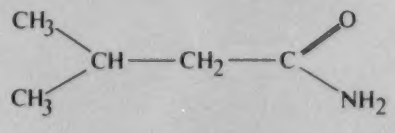
An aqueous solution of ethanamine, $CH_3CH_2NH_2$, has a characteristic 'fishy' smell. This smell can be removed by addition of

A sodium hydroxide solution.
B dilute hydrochloric acid.
C ethanol.
D dichloromethane.

U7 Amides

U7-1 60 **D**

Consider the compound



This compound is best described as an

A aldehyde. **B** amine. **C** amino acid. **D** amide.

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143

U7-2
40
D

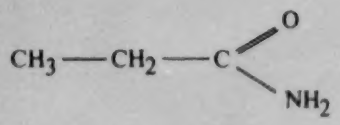
Which one of the following compounds is an amide?

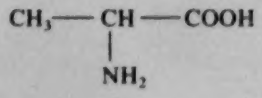
A $CH_3CH_2NH_2$
B $CH_3CHOHNH_2$
C H_2NCH_2COOH
D CH_3CONH_2

U7-3
60
C

The reaction between propanoic acid and excess ammonia gas at a high temperature is a means of producing propanamide, which can be represented by the formula

A $CH_3COO^-NH_4^+$

C 

B 

D $CH_3CH_2CH_2NH_2$

U8 Amino acids

U8a Identity, Structure

U8a-1
70
B

The molecule $CH_3CH(NH_2)COOH$ is an example of

A a protein.
B an amino acid.
C a peptide.
D a nucleic acid.

U8a-2
40
D

Which of the following compounds is an amino acid?

A ethanamine (ethylamine)
B cytosine
C DNA
D glycine

U8a-3
60*
D

Which one of the following compounds does **not** have a structure based on a cyclic arrangement of atoms in the solid state?

A glucose
B benzene
C cellulose
D alanine

U8b Properties

U8b-1
50
A

The proteins in the food eaten by animals are digested into amino acids.

Which of the following is **not** a property of most amino acids?

A They are highly soluble in non-polar organic solvents.
B They may be positively or negatively charged.
C They may act as both acids and bases.
D They can undergo condensation polymerization, forming polypeptides.

U8b-2
50
C

The amino acid glycine may exist in aqueous solution in several forms.
Which of the following would be the major component in strongly basic solution?

A NH_2-CH_2-COOH
B $NH_3^+-CH_2-COOH$
C $NH_2-CH_2-COO^-$
D $NH_3^+-CH_2-COO^-$

U8b-3
50
C

The actual state of an amino acid in aqueous solution depends on the pH of the solution. The molecule glycine, H_2NCH_2COOH, is most likely to exist as

A $^+H_3NCH_2COO^-$ at pH 12.
B $^+H_3NCH_2COO^-$ at pH 2.
C $^+H_3NCH_2COOH$ at pH 2.
D $^+H_3NCH_2COOH$ at pH 12.

U8b-4
60
A

A zwitter-ion is a species which contains both positive and negative charges. Which of the following can act as a zwitter-ion in aqueous solution?

A alanine
B ethanoic (acetic) acid
C ethanol
D glucose

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U8b-5
40
D

If an electric current were passed through a solution containing zwitter-ions, the zwitter-ions would

A migrate towards the positive electrode.
B migrate towards the negative electrode.
C decompose, producing anions and cations.
D not migrate towards the electrodes.

U8b-6
20
C

When the pH of an aqueous solution of glycine is 6.064, the glycine does not migrate towards the anode or the cathode when the solution is electrolysed. At this pH the glycine is mainly present as

A equal amounts of $NH_3^+CH_2COOH$ and $NH_2CH_2COO^-$.
B neutral protein molecules.
C the dipolar species $NH_3^+CH_2COO^-$.
D the cationic species $NH_3^+CH_2COOH$.
E neutral molecules of NH_3 and CH_3COOH.

U8b-7
50*
A

If an aqueous solution of the amino acid $NH_2CH_2(CH_3)COOH$ at a pH of 12 were electrolysed,

A $NH_2CH(CH_3)COO^-$ ions would migrate towards the anode.
B $NH_2CH(CH_3)COO^-$ ions would migrate towards the cathode.
C $NH_3^+CH(CH_3)COOH$ ions would migrate towards the anode.
D $NH_3^+CH(CH_3)COOH$ ions would migrate towards the cathode.

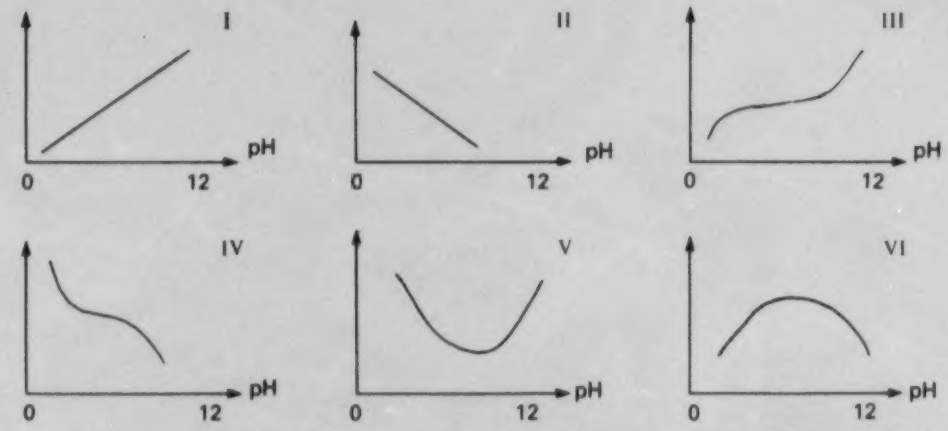
U8b-8
40
D

When a solution of alanine at a pH of 6.0 is electrolysed, the alanine does not migrate towards the anode or the cathode.

Which of the amino acids below would be most likely to migrate towards the cathode at this pH?

A $HOOCCH_2CH(NH_2)COOH$
B $(CH_3)_2CHCH(NH_2)COOH$
C $C_6H_5CH_2CH(NH_2)COOH$
D $H_2N(CH_2)_4CH(NH_2)COOH$

The next item refers to the following graphs



U8b-9
20
E

The graph which best represents the relationship between the conductivity of a glycine solution and pH is

A I. **B** II. **C** III. **D** IV. **E** V. **F** VI.

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U8c Role in biochemical systems

U8c-1 60 **D**

Amino acids from plants are important components in the diet of most animals. Plants usually obtain amino acids by

A reaction of plant carbohydrates with atmospheric nitrogen during photosynthesis.
B direct absorption of amino acids from the soil through the plant roots.
C breaking down starch and cellulose into their constituent amino acids.
D reaction of organic material in plants with nitrates and ammonium ions absorbed from the soil.

U8c-2 60 **A**

Certain amino acids are needed in our diet. These are called essential amino acids because

A they are not readily synthesized by the human body.
B they are used by humans in order to manufacture proteins.
C humans need them to make energy-storing carbohydrates.
D they contain hydrogen atoms which are capable of forming hydrogen bonds in DNA.

U9 Proteins

U9a Structure

U9a-1 40 **D**

A substance with the structure

$$\ldots -NH-CH_2-CO-NH-CH_2-CO-NH_2-CH_2-CO- \ldots$$

is likely to be

A a nylon.
B an amino acid.
C a nucleic acid.
D a protein.

U9a-2 20 **B**

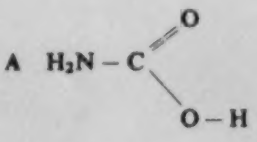
The elements present in proteins are

A C, H, O, N only.
B C, H, O, N, S only.
C C, H, O, N, S, P only.
D C, H, O, N, P only.

U9a-3 70 **B**

The peptide link is the group of atoms which bond amino acids into proteins.
A structural representation of the peptide link is

A



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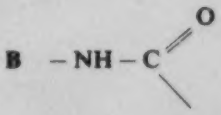

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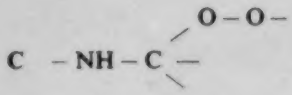

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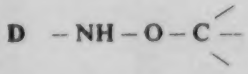

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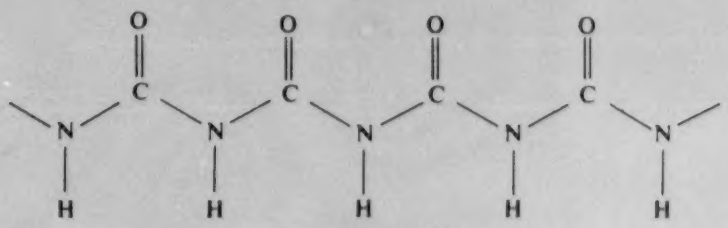
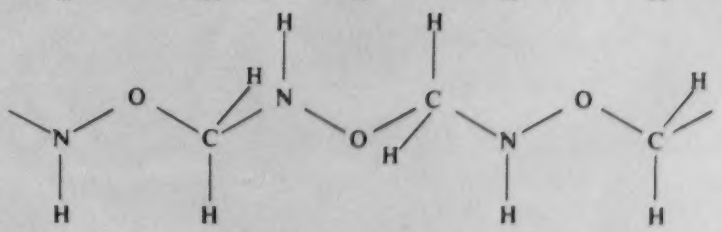
U9a-4 50 **C**

Which of the structural formulae below could represent a segment of a polypeptide chain formed from glycine?

A



B



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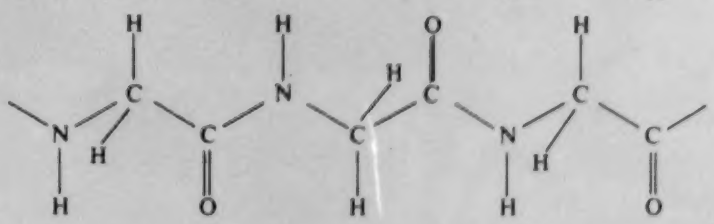

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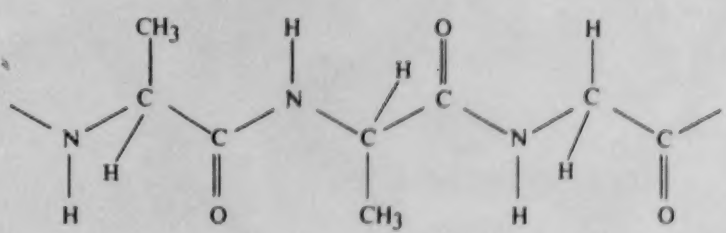

U9a-5 30 **A**

The structure of protein can be discussed by distinguishing four structural levels — primary, secondary, tertiary and quaternary. The sequence of amino acid residues in the polypeptide chain is referred to as the

A primary structure.
B secondary structure.
C tertiary structure.
D quaternary structure.

U9a-6 40 **B**

Hydrogen bonding is **not** a significant factor in establishing the

A helical structure of DNA.
B primary structure of a protein.
C structure of ice.
D secondary structure of a protein.

U9a-7 90* **D**

A protein can be regarded as a polymer formed from

A glucose.
B sugar, nitrogen bases and phosphate.
C hydrocarbon monomers.
D amino acids.

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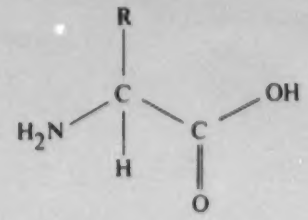
U9a-8
50
D

The general structure of an α-amino acid can be represented by the formula



where R is H or an organic group.

A polypeptide is a polymer formed from amino acid monomers. The synthesis of such a polymer involves

A a condensation reaction resulting in the elimination of a molecule of CO_2.
B an addition reaction between the C=O bonds in adjacent molecules.
C an addition reaction which forms a peptide link.
D a condensation reaction resulting in the elimination of a molecule of H_2O.

U9a-9
60
C

The percentage of oxygen by mass in the amino acid proline is 28%.
The percentage of oxygen by mass in a polypeptide formed from proline will be

A 28%. **B** more than 28%. **C** less than 28%.

U9a-10
10
B

A polypeptide chain is formed from 20 molecules of glycine, H_2NCH_2COOH.
The relative molecular mass of the chain would be (given A_r: O=16, N=14, C=12, H=1)

A 1140. **B** 1158. **C** 1177. **D** 1500.

U9b Properties

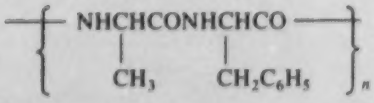
U9b-1
30
B

A biologist isolated a high molecular mass chemical from some living tissue. He found that it contained the elements carbon, nitrogen, hydrogen, and oxygen, that it was insoluble at high and low pH, and that it was made up of numerous sub-units.
Further investigations would probably show that

A the sub-units are identical.
B the sub-units are separable by hydrolysis.
C the sub-units are linked by carbon–carbon single bonds.
D the sub-units become negatively charged at low pH.

U9b-2
30
E

Which of the compounds below are most likely to be formed when a man digests a polypeptide with the structural formula



A $H_2NCH(CH_3)CONHCH(CH_3)COOH$ and C_6H_6

B CO_2, H_2O and NH_3

C $H_2NCH_2CH_3$ and $HCONHCH(CH_2C_6H_5)COOH$

D $H_2NCH(CH_3)COH$ and $H_2NCH(CH_2C_6H_5)CH_2OH$

E $H_2NCH(CH_3)COOH$ and $H_2NCH(CH_2C_6H_5)COOH$

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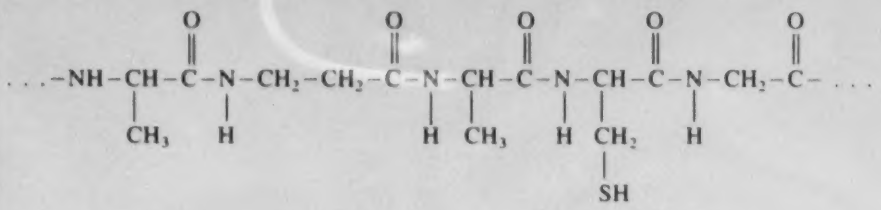
U9b-3 20 **C,E**

Which **two** of the following amino acids are **not** likely hydrolysis products of the part of the polypeptide shown?



A $CH_3CH(NH_2)COOH$

B $HSCH_2CH(NH_2)COOH$

C $CH_3SCH(NH_2)COOH$

D H_2NCH_2COOH

E $H_2NCH(CH_3)CH_2COOH$

U9b-4 40 **D**

The symbols Ala, Gly and Phe are used to represent amino acid residues derived from alanine, glycine and phenylalanine. A particular pentapeptide yields H.Ala.Gly.OH, H.Gly.Ala.OH, H.Phe.Gly.OH and other products when it is partially hydrolysed. On complete hydrolysis it produces 3 mol of glycine, 1 mol of alanine and 1 mol of phenylalanine.

The structure of the pentapeptide could be

A H.Gly.Ala.Phe.Gly.Gly.OH

B H.Phe.Gly.Ala.Gly.Ala.OH

C H.Ala.Gly.Ala.Gly.Phe.OH

D H.Phe.Gly.Ala.Gly.Gly.OH

U9b-5 60 **A**

Compounds other than carbon dioxide and water would be formed upon complete combustion in oxygen of

A protein.

B starch.

C ethanoic (acetic) acid.

D benzene.

U9b-6 50 **A**

Sulfur dioxide is formed when coal is burned. Since it is believed that coal was formed from plant material, it is likely that the sulfur was once a constituent of

A protein. **B** carbohydrate. **C** DNA. **D** cellulose.

U9c Urea

U9c-1 30 **C**

Proteins may serve as a source of energy for man if eaten in excess. The nitrogen in the protein is mainly excreted as

A NH_3.

B NH_4Cl.

C H_2NCONH_2.

D NH_2COOH.

E $CH_3CH_2NH_2$.

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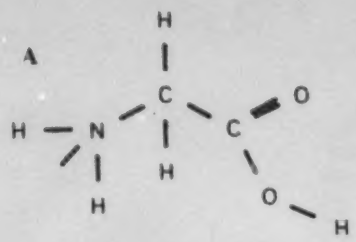
U9c-2
50
D

A build-up of nitrogen-containing waste products in the human body would lead to illness and eventual death.

Which of the following structures is most likely to represent a major human nitrogen-containing excretion product?

A



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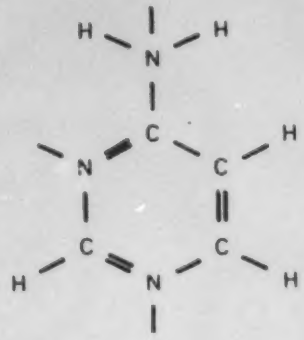

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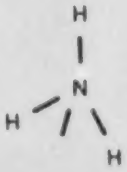

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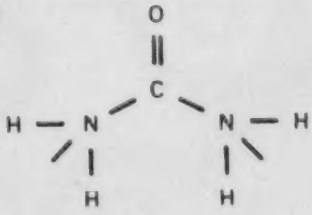

U9d Enzymes

U9d-1
80*
A

The role of enzymes as catalysts in biochemical processes is of vital importance. Enzymes are polymers synthesized from

A amino acids.
B glucose.
C nitrogen bases, sugars and phosphates.
D hydrocarbon molecules.

U9d-2
80
D

A characteristic of enzymes is that

A they increase the rate of any chemical reaction in a living system.
B they are much more reactive than protein molecules.
C they function best in neutral solutions.
D they specifically catalyze particular chemical reactions.

U9d-3
50
B

Which one of the following statements about enzymes is **incorrect?**

A They all contain proteins.
B They will show greater catalytic action at 100 °C than at 37 °C.
C They often require the presence of metal ions to exhibit their optimum activity.
D Many can be isolated as crystalline compounds.

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U10 Nucleic acids

U10-1 50* **D**

Nucleic acids can be regarded as polymers made from

A sugar groups and phosphate groups.
B phosphate groups, nitrogen bases and amino acids.
C essential amino acids.
D sugar groups, phosphate groups and nitrogen bases.

U10-2 60 **D**

Which one of the following lists contains only substances found in a DNA molecule?

A phosphate groups, glucose, alanine
B glycine, cytosine, phosphate groups
C cytosine, guanine, glucose
D adenine, cytosine, thymine

U10-3 50 **D**

The elements present in nucleic acids are

A C, H, O, N only.
B C, H, O, N, S only.
C C, H, O, N, S, P only.
D C, H, O, N, P only.

U10-4 40* **C**

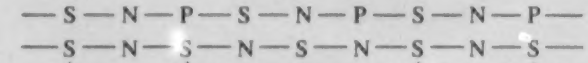
A DNA molecule is believed to be constructed from two intertwined strands. These strands contain a sequence of

A phosphate groups and nitrogen bases attached to a backbone of sugar residues.
B phosphate groups attached to a backbone of sugar residues and nitrogen bases.
C nitrogen bases attached to a backbone of sugar residues and phosphate groups.
D sugar residues attached to a backbone of nitrogen bases and phosphate groups.

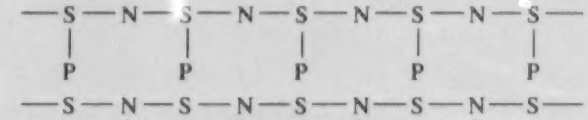
U10-5 60 **D**

A single strand of DNA contains sugar groups (S), phosphate groups (P) and nitrogen bases (N). The structure of a strand of DNA can be represented by

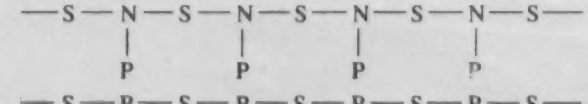
A



B



C



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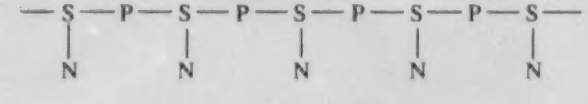

U10-6 40 **C**

Consider three of the important constitutents of living organisms — proteins, nucleic acids and bone tissue. Significant amounts of phosphorus occur in

A bone tissue only.
B proteins and nucleic acids only.
C nucleic acids and bone tissue only.
D proteins, nucleic acids and bone tissue.

U10-7 60 **C**

Watson and Crick proposed a structure for the DNA molecule, consisting of two chains wrapped around each other in a double helix.

The two chains are held together by

A dispersion forces between adjacent bases.
B covalent bonds between adjacent bases.
C hydrogen bonds between adjacent bases.
D peptide linkages between adjacent bases.

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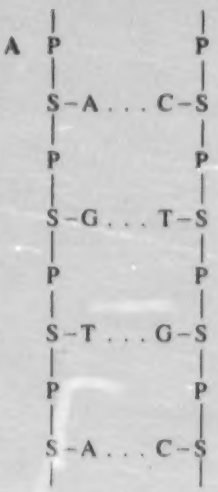
U10-8
40
D

DNA, which is the essential component of genes, consists of sugar groups (S), phosphate groups (P) and the nitrogen bases: adenine (A), glycine (G), thymine (T) and cytosine (C).

Which one of the diagrams below best represents part of a DNA molecule?

A



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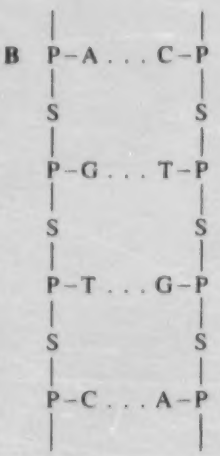

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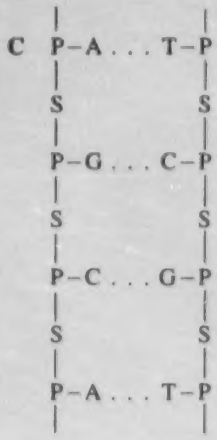

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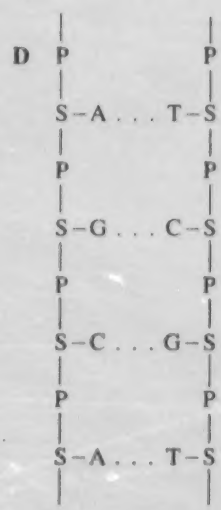

U10-9
70
C

It has been proposed that in a DNA molecule the

A total number of guanine and cytosine groups should be equal to the total number of adenine and thymine groups.

B numbers of adenine, thymine, guanine and cytosine groups depend upon the type of sugar incorporated in the backbone.

C number of guanine groups should be equal to the number of cytosine groups and the number of adenine groups should be equal to the number of thymine groups.

D numbers of adenine, thymine, guanine and cytosine groups should be equal.

U10-10
50*
D

The nitrogen bases in DNA are cytosine, adenine, guanine and thymine, which can be represented by the letters C, A, G, and T. If the sequence of bases in part of one strand is GATGCAT, the corresponding sequence of bases in the other strand would be

A AGTATGC.

B CTATGTA.

C GATGCAT.

D CTACGTA.

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U10-11 The helical structure of the two strands of a molecule of deoxyribonucleic acid is associated with

20

B

A a twisting effect induced by the close proximity of two strands composed of alternate phosphate and sugar units.

B bases linking to form base pairs of equal size, producing an approximately constant spacing between strands.

C the formation of disulfide links between strands and existence of ionic interactions between COO^- and NH_3^+ groups.

D non-linear hydrogen bonds formed between identical nitrogen bases on adjacent sections of the strands.

U10-12 In which one of the following substances would hydrogen bonding **not** play an important role in determining the structure and/or properties?

30

C

A liquid water

B a solid nucleic acid

C liquid methane

D a protein in aqueous solution

E liquid ammonia

U10-13 Which of the following statements about the double helix structure proposed for molecules of DNA is **incorrect?**

30*

A

A The sequence of nitrogen bases in the two strands of DNA is identical.

B The backbone of each strand in the molecule consists of alternating sugar and phosphate groups.

C The total number of guanine and cytosine groups may differ from the total number of adenine and thymine groups.

D The strongest bonds between the two strands in the molecule are hydrogen bonds.

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V PHOSPHORUS CHEMISTRY

V1 The element

V1a Occurrence

V1a-1 50 **C**

Which of the following elements is **not** found free in nature?

A sulfur **B** carbon **C** phosphorus **D** neon

V1a-2 40 **B**

The majority of the phosphorus in the earth's crust is present as

A solid P_4O_{10}.
B PO_4^{3-} ions.
C solid P_4O_6.
D solid P_4S_{10}.

V1b Structure

V1b-1 50 **C**

There are 3 main allotropes of phosphorus.
Which one of the following statements about the allotropes is correct?

A In each allotrope, the 15 electrons in each phosphorus atom are arranged in 3 orbitals.
B The chemical properties of each allotrope are identical, although the physical properties differ.
C In each allotrope, the phosphorus atoms have 5 valence electrons.
D The allotropes have different physical and chemical properties, although the arrangement of bonds within each allotrope is identical.

V1b-2 50 **A**

The shape of molecules of white phosphorus is

A tetrahedral.
B linear.
C trigonal planar.
D square pyramidal.
E square planar.

V1b-3 20 **A**

Black phosphorus is the most stable allotrope of phosphorus.
Its structure comprises a

A layer lattice in which each atom is bonded to three others.
B network lattice in which each atom is bonded to three others.
C layer lattice in which each atom is bonded to four others.
D network lattice in which each atom is bonded to four others.

V1b-4 70 **B**

Red phosphorus has a density of 2.35 g cm^{-3} and white phosphorus has a density of 1.82 g cm^{-3}. The red form has a higher density because

A the constituent atoms are smaller than those in the white form.
B the constituent atoms are more closely packed in the red form.
C the red form contains a phosphorus isotope which is not present in the white form.
D the white form has a giant molecular structure, whilst the red form is made up of layers of atoms.

V1c Preparation

V1c-1 60 **C**

Which of the reaction sequences below best outlines the substances involved in the extraction of molecular phosphorus from rock phosphate?

A $Ca_3(PO_4)_2 \rightarrow P_4O_6 \rightarrow$ white phosphorus
B $Ca_3(PO_4)_2 \rightarrow P_4O_6 \rightarrow$ red phosphorus
C $Ca_3(PO_4)_2 \rightarrow P_4O_{10} \rightarrow$ white phosphorus
D $Ca_3(PO_4)_2 \rightarrow P_4O_{10} \rightarrow$ red phosphorus

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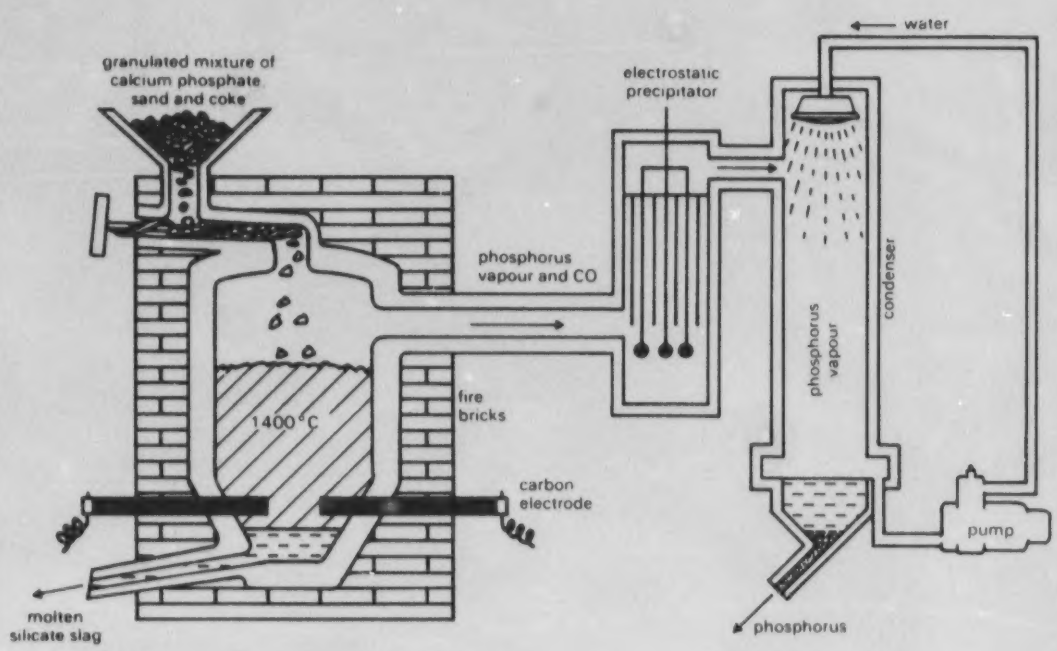
The next three items refer to the following diagram of a plant producing phosphorus.



V1c-2
50
C

The purpose of the coke is to

A oxidise PO_4^{3-} ions from calcium phosphate to P_4 molecules.
B oxidise SiO_2 from sand to SiO_3^{2-} ions.
C reduce P_4O_{10} molecules formed in the furnace to P_4 molecules.
D reduce atmospheric O_2 to CO, which acts as an inert atmosphere.

V1c-3
70
D

The purpose of the carbon electrodes is to

A reduce the PO_4^{3-} ions to P_4, and oxidise SiO_2 to SiO_3^{2-}.
B reduce PO_4^{3-} ions to P_4, and oxidise carbon to CO.
C electrostatically attract the molten silicate slag to the bottom.
D allow current to pass through the mixture, thereby generating heat.

V1c-4
90
B

The phosphorus is initially produced in the plant in the form(s) of

A red phosphorus.
B white phosphorus.
C black phosphorus.
D a mixture of more than one allotrope of phosphorus.

V1c-5
50*
C

White phosphorus is usually prepared by

A electrolysis of a molten solution containing PO_4^{3-} ions.
B reduction of rock phosphate with CO gas formed by heating coke in air.
C conversion of PO_4^{3-} ions to P_4O_{10} followed by reduction by coke.
D roasting a mixture of rock phosphate and sulfur in the presence of oxygen.

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V1d Properties

V1d-1 80 C

The allotropes of phosphorus, from most reactive to least reactive are

A red, black, white.
B red, white, black.
C white, red, black.
D white, black, red.
E black, red, white.
F black, white, red.

V1d-2 40 A

When white phosphorus is exposed to air it emits a pale green glow and eventually bursts into flame. To prevent this, it is normally stored under

A water.
B kerosene.
C paraffin oil.
D ethanol.

V1d-3 60 D

Compared with white phosphorus, red phosphorus

A melts at a lower temperature.
B is less dense and a poorer conductor of electricity.
C is more soluble in non-polar solvents.
D is less volatile and less reactive.

V1d-4 30 A

White phosphorus ignites in air at temperatures above 35 °C, whereas red phosphorus must be heated to 240 °C before it ignites. The higher reactivity of white phosphorus can be partly explained by the

A severely strained bonds in molecules of white phosphorus.
B presence of double bonds which can be readily attacked by oxygen.
C existence of unfilled orbitals in the outer shell of phosphorus atoms in white phosphorus.
D dipolar nature of the bonds in white phosphorus.
E higher strength of the P-P bonds in white phosphorus compared with P-O bonds.

V1d-5 50 A

Compared with white phosphorus, red phosphorus has a

A higher melting temperature and is less reactive with air.
B higher melting temperature and is more reactive with air.
C lower melting temperature and is less reactive with air.
D lower melting temperature and is more reactive with air.

V2 Phosphorus oxides and oxo acids

V2-1 50 B

The product formed when black phosphorus is burnt in excess air is

A PO_2.
B P_4O_{10}.
C PO_3.
D P_4O_6.

V2-2 40 C

A sealed flask containing white phosphorus and air is strongly heated. If the contents of the flask were then allowed to return to room temperature, it would be most likely that

A the gas pressure in the flask would be unchanged.
B the mass of the flask would have increased.
C the gas pressure in the flask would have decreased.
D the mass of the flask would have decreased.

V2-3 60 C

Addition of excess cold water to phosphorus (III) oxide produces

A a neutral solution.
B H_3PO_4.
C H_3PO_3.
D a mixture of H_3PO_3 and H_3PO_4.

V2-4 50* B

Addition of excess hot water to phosphorus(V) oxide produces a

A neutral solution.
B solution of H_3PO_4.
C solution of H_3PO_3.
D solution of H_3PO_3 and H_3PO_4.

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V2-5
60
C

Many chemical processes involve the use of a dehydrating agent—a chemical which absorbs water from its surroundings.

An example of the reaction of such a chemical is

A the conversion of P_4O_6 to P_4O_{10} and H_3PO_3, by reaction with water.
B the conversion of P_4O_{10} to H_3PO_3 and H_3PO_4, by reaction with water.
C the conversion of P_4O_{10} to H_3PO_4, by reaction with water.
D the conversion of P_4O_6 to H_3PO_4 by reaction with water.

V2-6
40
B

Phosphoric acid is used in making high-purity sodium and potassium phosphates for use in the soap and detergent industry.

The sequence of phosphorus compounds produced in the industrial preparation of phosphoric acid from white phosphorus is best written as

A $P_4 \rightarrow P_4O_6 \rightarrow H_3PO_4$.
B $P_4 \rightarrow P_4O_{10} \rightarrow H_3PO_4$.
C $P_4 \rightarrow P_4O_6 \rightarrow H_3PO_3 \rightarrow H_3PO_4$.
D $P_4 \rightarrow P_4O_6 \rightarrow P_4O_{10} \rightarrow H_3PO_3 \rightarrow H_3PO_4$.

V2-7
60
B

Phosphoric acid, H_3PO_4, may be prepared by

A burning white phosphorus in oxygen to give P_4O_6 and reacting the P_4O_6 with hot water.
B burning white phosphorus in oxygen to give P_4O_{10} and reacting the P_4O_{10} with hot water.
C reacting white phosphorus directly with hot water.
D reacting white phosphorus directly with a concentrated solution of hydrochloric acid.

V3 Phosphates

V3-1
90*
A

The majority of the phosphorus present on earth is in the form of calcium phosphate. Calcium phosphate is found mainly in the human body in

A bone. B DNA. C protein. D urine.

V3-2
50*
D

Which one of the following compounds is a major constituent of bone?

A $CaHPO_4$ B $CaCO_3$ C $Ca(HCO_3)_2$ D $Ca_3(PO_4)_2$

V3-3
50
B

Which of the following compounds is the **least** soluble in water?

A NH_4NO_3 B $Ca_3(PO_4)_2$ C H_2NCONH_2 D CH_3COOH

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W OXYGEN CHEMISTRY

W1 The element

W1-1
90
B

Oxygen is obtained from liquid air by

A catalytic oxidation.
B fractional distillation.
C catalytic cracking.
D electrolytic decomposition.

W1-2
30
B

When elemental oxygen is prepared from its compounds the process is usually

A highly exothermic and involves an increase in the oxidation number of the oxygen atom.
B highly endothermic and involves an increase in the oxidation number of the oxygen atom.
C highly exothermic and involves a decrease in the oxidation number of the oxygen atom.
D highly endothermic and involves a decrease in the oxidation number of the oxygen atom.
E highly exothermic and involves no change in the oxidation number of the oxygen atom.

W1-3
70*
A

Ozone, O_3, is usually produced in the laboratory by

A passing an electrical discharge through oxygen.
B heating pure oxygen in the presence of platinum.
C thermal decomposition of alkali metal nitrates.
D oxidation of hydrogen peroxide by solutions of potassium permanganate.

W2 Water

W2-1
30
C

The water molecules in ice are essentially bonded to each other by attractions between

A instantaneous dipoles within each water molecule.
B instantaneous ion-dipole interactions formed between adjacent water molecules.
C permanent dipoles within each water molecule.
D permanent ion-dipole interactions formed between adjacent water molecules.

W2-2
20
B

Aquatic life in cold climates is dependent on the ability of ice to float on water.

Chemists explain the lower density of ice compared with that of water in terms of their structures. A major feature of the structure of ice is that it consists of H_2O molecules

A arranged in an infinite covalent network lattice similar to diamond.
B arranged so that each molecule is surrounded by four others.
C arranged so that hydrogen bonding occurs between hydrogen atoms on adjacent molecules.
D bonded to each other by ion-dipole attractions.

W2-3
90
D

Water is a possible contaminant in jet fuel (kerosene) and may form separate layers in an aircraft's fuel tank.

Water and kerosene form separate layers when mixed together because

A both are polar substances.
B both are non-polar substances.
C they have the same densities.
D one is polar and one is non-polar.

W2-4
30*
A

A polar substance is dissolved in water. Which of the following solvents is most likely to precipitate the substance if it is added to the solution?

A methanol
B carbon tetrachloride
C benzene
D paraffin oil

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W2-5 80 C

Hydrated aluminium chloride contains the complex ion $Al(H_2O)_6^{3+}$. The bonding between aluminium and water in this ion is best described as being

A covalent bonding.
B ionic bonding.
C ion-dipole bonding.
D hydrogen bonding.
E bonding due to dispersion forces only.

W2-6 80 B

The solubility of substances such as sodium chloride in water is largely a result of the formation of

A covalent bonds.
B ion - dipole bonds.
C dispersion forces.
D hydrogen bonds.

W2-7 60* A

Sodium bromide has been used as a sedative. The most likely form of administration to humans is as a

A solution in water.
B solution in a non-polar solvent.
C suspension in water.
D gaseous inhalation.

W3 Hydrogen peroxide

W3-1 60 B

Which **one** of the following statements **best** describes the behaviour of H_2O_2?
It can be

A oxidized to H_2O or reduced to O_2.
B oxidized to O_2 or reduced to H_2O.
C oxidized to H_2O but does not undergo reduction.
D oxidized to O_2 or reduced to H_2.

W3-2 30* D

Hydrogen peroxide undergoes several types of reactions, depending on the nature of the other reactant. However it does **not** usually act as

A an oxidant.
B an acid.
C a reductant.
D a dehydrating agent.

W3-3 80 C

A characteristic of the behaviour of hydrogen peroxide in chemical reactions is that it can behave as

A an oxidant but not as a reductant.
B a base but not as an acid.
C both an oxidant and as a reductant.
D a powerful dehydrating agent.

W3-4 20 C

Hydrogen peroxide is often used as a bleaching agent — for example, it may be used to lighten the colour of hair.
In such a reaction, the H_2O_2

A reacts with natural body acids to produce O_2 and OH^-.
B reacts with oxidants present in hair to produce O_2.
C is reduced to H_2O by chemicals present in hair.
D catalyses the breakdown of pigment molecules present in hair.

W3-5 40 A

A reaction occurs when a quantity of concentrated hydrogen peroxide solution is added to a solution of sodium iodide. The reaction will

A increase the pH of the solution.
B decrease the pH of the solution.
C have no effect on the pH of the solution.

W3-6 80 D

Hydrogen peroxide is used in a variety of applications. It is **not** used as

A a rocket fuel.
B a bleaching agent.
C an antiseptic.
D a fertilizer.

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X SULFUR CHEMISTRY

X1 The element

X1-1 90 A

Sulfur can exist in several structural forms at room temperature. These forms are known as

A allotropes.
B homologues.
C isomers.
D isotopes.

X1-2 40 C

The substance obtained when boiling sulfur is poured into ice-water contains

A chair-shaped S_6 molecules.
B planar S_8 molecules.
C long helical chains.
D puckered S_8 molecules.
E S_2 molecules.

X1-3 20* A

A variety of structural forms of sulfur have been identified by chemists. The following species occur in some of these structural forms:

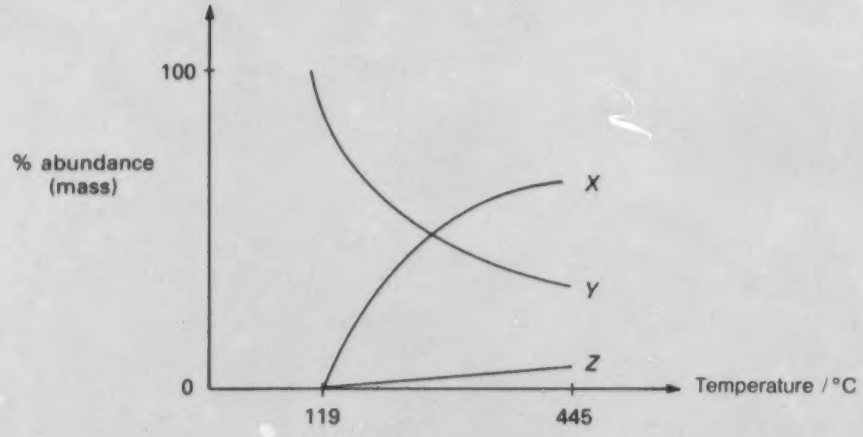
I S_8 molecules
II S_6 molecules
III long helical chains

The species found in the rhombic (S_α) and monoclinic (S_β) forms of sulfur are, respectively,

A I, I.
B I, II.
C I, III.
D II, I.
E II, III.

X1-4 20* E

Liquid sulfur can be regarded as being composed of S_6 molecules, polymer chains and S_8 molecules. The graph below shows the approximate abundance of the three species from the melting temperature to the boiling temperature of sulfur.



Curves *X*, *Y* and *Z* represent, respectively,

A S_8 molecules, polymer chains, S_6 molecules.
B S_8 molecules, S_6 molecules, polymer chains.
C S_6 molecules, S_8 molecules, polymer chains.
D S_6 molecules, polymer chains, S_8 molecules.
E polymer chains, S_8 molecules, S_6 molecules.

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X1-5 | 80 | D

Sulfur exists in a number of molecular forms. S_2 molecules are most likely to be found in

A S_α (rhombic sulfur).
B S_β (monoclinic sulfur).
C S_ρ (rhombohedral sulfur).
D sulfur vapour.

X1-6 | 60 | A

The most stable structure of sulfur at room temperature is the

A rhombic form.
B monoclinic form.
C amorphous form.
D rhombohedral form.

X1-7 | 10 | D

Rhombic sulfur (S_α) can be prepared from monoclinic sulfur (S_β) by

A prolonged heating of the sulfur at temperatures above 95.5 °C.
B pouring molten sulfur into ice-water.
C adding concentrated hydrochloric acid to a solution of the sulfur in carbon disulfide at −10 °C.
D evaporating the solvent from a solution of sulfur in carbon disulfide at room temperature.

X1-8 | 90 | C

An unusual property of sulfur is that, when it is heated beyond its melting temperature, its viscosity first increases before decreasing.

A possible explanation for this is that

A sulfur atoms are arranged in rings which become entangled at moderate temperatures.
B the increase in temperature causes the chains of sulfur atoms to break up, thus increasing the number of molecules present.
C as the temperature increases, the sulfur rings first break up to form long chains, which themselves break up on further heating.
D as the temperature increases, the sulfur chains form larger and larger rings, which gradually become entangled.

X1-9 | 70 | D

Which one of the following alternatives lists sulfur compounds in order of increasing oxidation number of sulfur?

A S; H_2S; SO_2; SO_3.
B S; SO_2; H_2SO_3; H_2SO_4.
C H_2S; S; SO_2; H_2SO_3.
D H_2S; S; SO_2; SO_3.

X2 Sulfur oxides

X2-1 | 40 | C

When sulfur burns in air the combustion product is

A an oxide containing O^{2-} ions.
B a gas which dissolves in water forming sulfuric acid.
C an oxide which reacts with water to form a weak acid.
D a gas with a 'rotten egg' odour.

X2-2 | 10 | C

A student found that a gas had the following properties:

I it was colourless and fumed in moist air
II it had a choking odour
III it dissolved readily in water forming an acidic solution
IV when the gas was passed into concentrated nitric acid a brown gas was formed

The student could reasonably conclude that the gas might be

A SO_3. B NH_3. C SO_2. D NO_2. E CO.

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X2-3
50
A

High concentrations of SO_2 have been blamed for the increased mortality rates occurring in times of 'smog'.

Which of the following processes would **not** release SO_2 into the atmosphere?

A the action of water on superphosphate fertilisers
B the combustion of crude oil
C the oxidation of sulfide ores in a smelter
D the emission of gases from a plant using the 'contact' process

X2-4
40
C

'Reducing smog' has been responsible for thousands of deaths in some of the larger industrial cities of the world. The smog results from the presence in the atmosphere of

A NO_x, O_2 and hydrocarbons.
B NO_x, O_2 and particulate matter.
C SO_2 and particulate matter.
D SO_2, CO and NO_x.

X2-5
50
B

Passage of sulfur dioxide through water produces

A a neutral solution.
B sulfurous acid.
C sulfuric acid.
D an equimolar mixture of sulfurous and sulfuric acid.

X2-6
50
B

Which of the following oxides forms the strongest acid when dissolved in water?

A CO_2 **B** SO_3 **C** NO **D** SiO_2

X2-7
50*
B

Passage of sulfur trioxide gas through a concentrated solution of sodium hydroxide is likely to form the species

A $(HO)_2SO_2$.
B SO_4^{2-}.
C HSO_3^-.
D $(HO)_2SO$.
E SO_3^{2-}.

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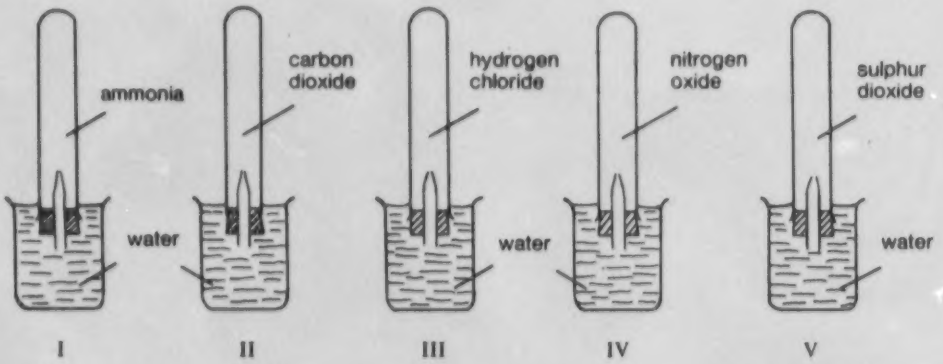
The next three items refer to the following information

Five test-tubes, containing only the pure gases ammonia, carbon dioxide, hydrogen chloride, nitrogen oxide and sulfur dioxide, were each fitted with a rubber stopper and a short piece of glass tubing. These test-tubes were each immersed in a beaker containing water, as shown in the diagrams below. The water was observed to enter each test-tube, more rapidly in some cases than others.



X2-8 40 **A**

In which of the following cases would the water squirt rapidly into the test-tubes?

A I, III and V only.
B I, II and IV only
C II, III and V only
D II, IV and V only

X2-9 40 **A**

In which one of the following cases would the pH of the water increase when it entered the test-tube?

A I only
B III only
C I and III only
D II and V only
E II, III and V only

X2-10 30 **C**

In which one of the following cases would the pH of the water remain unchanged when it entered the test-tube?

A II only
B III only
C IV only
D IV and V only
E II and V only

The next two items refer to the following equation

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \qquad \Delta H \rightleftharpoons -760 \text{ kJ mol}^{-1}$$

X2-11 70 **B**

Conditions which would favour a high equilibrium yield of SO_3 from the reaction of SO_2 and O_2 are

A high pressures and high temperatures.
B high pressures and low temperatures.
C low pressures and high temperatures.
D low pressures and low temperatures.

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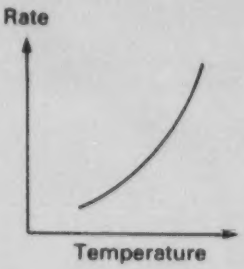
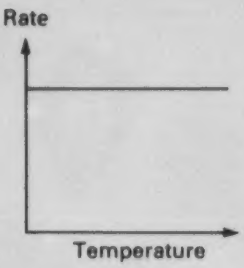
X2-12 40 **A**

Which of the following graphs best represents the effect of changing the temperature on the rate of production of SO_3?

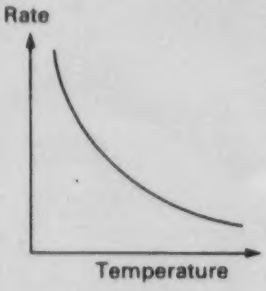
A



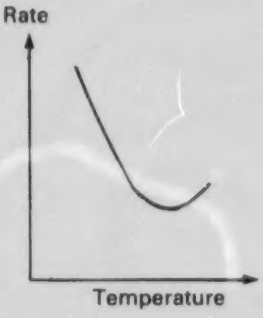
C



B



D



X2-13 40 **C**

One of the oxides below will **not** react with oxygen. Which one?

A P_4O_6 **B** CO **C** SO_3 **D** NO

X2-14 50* **B**

The production of SO_3 from SO_2 and O_2 is often carried out in the presence of complex vanadium(V) compounds, which act as catalysts for the reaction. In the equation below, V^{IV} and V^{V} mean complex compounds of vanadium with oxidation states of +4 and +5 respectively. Note that the physical states of the reactants have not been specified as there is some doubt about these.

Which one of the following pairs of (simplified) equations is most likely to correctly represent the catalytic reactions taking place in the reaction chambers which lead to the production of SO_3?

A $2V^{V} + SO_2 + O^{2-} \rightarrow 2V^{IV} + SO_3$
$2V^{V} + \frac{1}{2}O_2 \rightarrow 2V^{IV} + O^{2-}$

B $2V^{V} + SO_2 + O^{2-} \rightarrow 2V^{IV} + SO_3$
$2V^{IV} + \frac{1}{2}O_2 \rightarrow 2V^{V} + O^{2-}$

C $2V^{V} + SO_2 + O^{2-} \rightarrow 2V^{IV} + SO_3$
$2V^{V} + O^{2-} \rightarrow 2V^{IV} + \frac{1}{2}O_2$

D $2V^{IV} + SO_3 \rightarrow 2V^{V} + SO_2 + O^{2-}$
$2V^{V} + O^{2-} \rightarrow 2V^{IV} + \frac{1}{2}O_2$

X3 Sulfuric acid

X3-1 50 **B**

The 'contact' process is the major source of the world's sulfuric acid.
Which of the following events would take place in industrial plants using this process?

A Oxygen is bubbled through liquid sulfur in the converter to form sulfur dioxide.
B Sulfur dioxide and oxygen are reacted catalytically to form sulfur trioxide.
C Sulfur trioxide and water are reacted catalytically to produce sulfuric acid.
D Pure sulfuric acid is separated from the water by fractional distillation.

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X3-2 60 **C**

One of the reactions involved in the production of H_2SO_4 is given by the following equation.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightarrow SO_3(g) \qquad \Delta H = -380 \text{ kJ mol}^{-1}$$

In industrial plants, this reaction takes place at moderately high temperatures, because

A the equilibrium constant is too low at low temperatures.
B SO_2 is a liquid at room temperature.
C the rate of reaction is low at room temperature.
D the SO_2 used is already at a high temperature from the previous reaction.

X3-3 60 **C**

The contact process involves the synthesis of SO_3 from SO_2, which is then hydrolyzed to H_2SO_4. No external heating is used in the conversion of SO_2 to SO_3 because

A SO_3 is formed spontaneously from SO_2 and O_2 at room temperatures.
B in this instance the rate of the reaction is faster at low temperatures.
C the reaction supplies sufficient heat to maintain the required temperatures.
D hot SO_3 reacts vigorously with water forming a fog of sulfuric acid and pyrosulfuric acid droplets.

X3-4 50* **A,B**

Five reactions that may occur during the industrial production of sulfuric acid are given below. In which **one or more** of these reactions is sulfur oxidized?

A $S + O_2 \rightarrow SO_2$
B $2SO_2 + O_2 \rightarrow 2SO_3$
C $SO_3 + H_2O \rightarrow H_2SO_4$
D $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$
E $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

X3-5 50 **C**

A feature of the reaction between sulfuric acid and glucose is that

A each sulfuric acid molecule donates protons to a glucose molecule.
B each glucose molecule is rapidly oxidised by sulfuric acid to carbon dioxide and water.
C sulfuric acid extracts hydrogen and oxygen from glucose leaving only carbon.
D the heat evolved in this exothermic reaction causes the combustion of the glucose.

X3-6 30 **B**

A major product from the reaction that occurs when formic acid, HCOOH, is warmed with concentrated sulfuric acid is

A CH_4. **B** CO. **C** SO_3. **D** CH_3OH.

X3-7 40 **A**

Concentrated sulfuric acid can act as an acid, as an oxidizing agent or as a dehydrating agent.

When a small amount of concentrated nitric acid is added to concentrated sulfuric acid the nitric acid initially accepts a proton, forming $(HO)_2NO^+$, which then reacts with more sulfuric acid to form

A NO_2^+. **B** N_2. **C** NO^+. **D** $(HO)_3N$.

X3-8 20 **B**

Which of the following is **least** likely to be produced if sulfuric acid were added to a reactive metal?

A S **B** SO_3 **C** SO_2 **D** H_2S

X3-9 30 **D**

When concentrated H_2SO_4 is mixed with solid KBr, both of the following reactions occur.

$$H_2SO_4 + KBr \rightarrow HBr + KHSO_4 \quad \ldots \text{I}$$
$$2H_2SO_4 + 2KBr \rightarrow Br_2 + SO_2 + K_2SO_4 + 2H_2O \quad \ldots \text{II}$$

In reactions I and II H_2SO_4 is acting as, respectively,

A an acid, and a reductant.
B an acid, and a dehydrating agent.
C an oxidant, and an acid.
D an acid, and an oxidant.

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X3-10 30 **C**

Nitric acid may be prepared for use in the laboratory by heating a mixture of sodium nitrate with sulfuric acid. This preparative method relies upon the fact that

A the nitrate ion is a stronger reductant than sulfuric acid.
B sulfuric acid acts as a base in the presence of a stronger acid.
C sulfuric acid has a higher boiling temperature than nitric acid.
D hot sulfuric acid can be readily reduced to SO_2, S or H_2S.

X3-11 10 **A**

Which one of the following chemicals is used in the manufacture of superphosphate fertilizer?

A H_2SO_4 **B** H_3PO_4 **C** $Ca(H_2PO_4)_2$ **D** $CaSO_4$

X4 Hydrogen sulfide

X4-1 70 **C**

Which of the following describes the shape of molecules of hydrogen sulfide?

A linear **B** tetrahedral **C** V-shaped **D** pyramidal

X4-2 70 **D**

Despite the fact that the molar mass of H_2S is approximately double that of H_2O, H_2S has a boiling temperature of $-62\ ^\circ C$, while that of H_2O is $100\ ^\circ C$ under the same pressure. This apparent anomaly is due to

A the weakly acidic nature of H_2O compared to H_2S.
B the greater reactivity of H_2S compared to H_2O.
C the stronger attraction between hydrogen atoms in H_2O compared with H_2S.
D the existence of stronger dipoles in liquid H_2O than in liquid H_2S.

X4-3 70 **C**

Water and hydrogen sulfide differ in that

A the H_2S molecule is linear, whereas the H_2O molecule is V-shaped.
B H_2S shows acidic properties whereas H_2O does not.
C the bonds between H_2O molecules are stronger than those between H_2S molecules.
D H_2S can be oxidized to S whereas H_2O cannot be oxidized to O_2.

X4-4 70 **D**

Water and hydrogen sulfide molecules are both V-shaped molecules and have a number of similar properties. Which one of the following statements about their properties is correct?

A H_2O is a stronger acid than H_2S.
B H_2O boils at a lower temperature than H_2S.
C Both H_2O and H_2S expand on freezing.
D H_2O is a weaker reductant than H_2S.

X4-5 30 **C**

Which of the following compounds is most likely to act as a reducing agent?

A HNO_3 **B** H_2SO_4 **C** H_2S **D** Cl_2 **E** P_4O_{10}

X4-6 50 **B**

Which one of the following substances will change the colour of an acidified solution of potassium dichromate from orange to green?

A carbon dioxide **C** sulfur trioxide
B hydrogen sulfide **D** nitrogen dioxide

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X4-7
20
B

When a lighted taper was plunged into a gas jar containing an unknown gas, the taper was extinguished but the gas burnt with a blue flame. The combustion products were shaken with water and an acidic solution was formed.

Of the following, the gas is most likely to be

A CO_2. **B** H_2S. **C** NH_3. **D** SO_2. **E** NO_2.

X4-8
40
B

When hydrogen sulfide gas is bubbled through a solution a black precipitate is formed. The precipitate could **not** be

A Ag_2S. **B** MgS. **C** PbS. **D** CuS.

X4-9
10*
A

An aqueous solution is known to contain some or all of the cations Al^{3+}, Cu^{2+} and Ag^+. Addition of sodium hydroxide to a sample of the solution gives a precipitate, whereas no precipitate is formed when hydrogen sulfide gas is passed through another sample of the solution.

The original solution probably contains

A Al^{3+} only.
B Ag^+ only.
C Al^{3+} and Cu^{2+} only.
D Al^{3+} and Ag^+ only.
E Cu^{2+} and Ag^+ only.

X4-10
40*
C

A white solid when dissolved in water formed no precipitate when H_2S gas was passed into the solution. When Na_2CO_3 solution was added to the original solution a precipitate resulted.

The white solid could be

A $Pb(NO_3)_2$. **B** NaCl. **C** $Ca(NO_3)_2$. **D** $CuSO_4$.

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Y HALOGEN CHEMISTRY

Y1 The elements

Y1a Structure

Y1a-1 40 **C**

In which of the following elements are intermolecular forces strongest?

A fluorine **B** bromine **C** iodine **D** chlorine

Y1b Properties

Y1b-1 40* **D**

All of a group of elements have the following properties:
low melting points, which increase down the group;
strong oxidizing properties, which decrease down the group;
the hydrides of the elements are acidic in solution, the acidity increasing down the group from moderate to very strong.

The group in the periodic table to which these elements belong is most likely

A group II. **B** group IV. **C** group VI. **D** group VII.

Y1b-2 80 **D**

The elements of group VII of the periodic table are highly coloured.

The element which exists as a brown red liquid at room temperature is

A fluorine. **B** iodine. **C** chlorine. **D** bromine.

Y1b-3 60 **B**

Compared with chlorine, bromine has a

A higher boiling temperature and is a stronger oxidant.
B higher boiling temperature and is a weaker oxidant.
C lower boiling temperature and is a stronger oxidant.
D lower boiling temperature and is a weaker oxidant.

Y1b-4 70 **B**

The reaction chemistry of the halogens is dominated by their tendency to act as oxidants.

In which of the following lists are halogens placed in **increasing** order of their strengths as oxidants?

A Cl < I < Br **C** I < Cl < Br
B I < Br < Cl **D** Cl < Br < I

Y1b-5 70 **D**

Which one of the four elements, hydrogen, bromine, iodine and chlorine, shows the greatest tendency to oxidize the other three?

A hydrogen **B** bromine **C** iodine **D** chlorine

Y1b-6 60 **B**

In an experiment, bromine gas is bubbled into a solution containing a mixture of chloride ions and iodide ions. It would be expected that the bromine would react with

A the chloride ions only.
B the iodide ions only.
C both the chloride ions and the iodide ions.
D neither the chloride ions nor the iodide ions.

Y1b-7 30 **A**

Which one of the following ions is the best reducing agent in neutral, aqueous solution?

A I^- **B** Cl^- **C** Br^- **D** F^- **E** OCl^-

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Y1b-8
50*
D

In which one of the following lists are the halide ions Br^-, Cl^- and I^- given in increasing order of their ability to act as reductants?

A $Br^- < I^- < Cl^-$
B $I^- < Br^- < Cl^-$
C $Cl^- < I^- < Br^-$
D $Cl^- < Br^- < I^-$

Y1b-9
50
B

Chlorine gas is often passed through large volumes of water to prevent the growth of algae and bacteria.

The chlorine reacts with water, forming

A hydrochloric acid only.
B hydrochloric and hypochlorous acids.
C hypochlorous and hypochloric acids.
D hydrochloric and hypochloric acids.

Y1b-10
70
C

The action of many household bleaching agents is a result of the oxidizing properties of hypochlorite ions.

Hypochlorite ions are formed by the reaction of

A sodium chloride and chlorine gas.
B sodium chloride and concentrated hydrochloric acid.
C chlorine gas and sodium hydroxide solution.
D metallic sodium and hydrogen chloride gas.

Y1b-11
30*
D

Which of the following species is formed in greatest abundance when chlorine is dissolved in water?

A $OCl^-(aq)$ **B** $OCl_2^-(aq)$ **C** $OCl_2^{2-}(aq)$ **D** $Cl^-(aq)$

Y1b-12
90
B

All the halogens react to a measureable extent with cold water, according to the equation

$$X_2 + H_2O \rightleftharpoons H^+ + X^- + HOX.$$

Which one of the following halogens reacts to the greatest extent?

A bromine **B** chlorine **C** iodine

Y1b-13
40
A

Conductivity measurements were performed on saturated aqueous solutions of chlorine, oxygen, iodine and bromine at 20 °C. The highest conductivity measurement would be obtained for the solution of

A chlorine. **B** oxygen. **C** iodine. **D** bromine.

Y1b-14
70
A

The oxidizing and bleaching properties of a solution prepared by bubbling chlorine through sodium hydroxide solution is best attributed to the presence of the species

A OCl^-. **B** Cl^-. **C** ClO_2^-. **D** H^+.

Y1b-15
30
B

Iodine has traditionally been used as a disinfectant for wounds in the skin. It is only slightly soluble in water but addition of sodium iodide causes the solubility to increase.

The change in solubility is mainly due to the formation of

A IO^-. **B** I_3^-. **C** HIO. **D** HI. **E** I_2O^-.

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Y2 Hypohalites

Y2-1
90
D

Which one of the following ions is commonly found in household bleaching agents?

A OCl_2 B OCl_2^{2-} C OCl^{2-} D OCl^-

Y2-2
70
C

Calcium hypochlorite is often added to domestic swimming pools to prevent the growth of algae. One of the greatest hazards associated with this chemical in a household is that it can

A absorb moisture from the skin, forming corrosive hypochlorous acid.
B spontaneously decompose, forming chlorine and oxygen gas.
C explosively oxidize common organic liquids like petrol.
D react vigorously with water, releasing poisonous chlorine gas.

Y3 Metal halides

Y3-1
40
C

Addition of dilute hydrochloric acid would clearly distinguish between solutions of

A barium nitrate and sodium sulfate.
B lead nitrate and silver nitrate.
C lead nitrate and barium nitrate.
D calcium nitrate and barium nitrate.

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Z METALS

Z1 Transition metal characteristics

Z1-1 80 **D**

The set of elements which characteristically form coloured compounds and show a number of oxidation states are

A alkali metals.
B alkaline earth metals.
C metals occurring in period 3.
D transition metals.

Z1-2 60 **D**

Transition metals can be distinguished from main group metals by the fact that

A main group metals, but not transition metals, must have a valency of +1 or +2.
B main group metals have lower relative atomic masses than transition metals.
C transition metals, but not main group metals, can form complex ions.
D transition metals have a greater tendency to form coloured salts than main group metals.

Z1-3 60 **B**

Which one of the following compounds dissolves in water to form a colourless solution?

A $CrCl_3$
B $Ca(NO_3)_2$
C $FeSO_4$
D $Cu(NO_3)_2$
E $NiSO_4$

Z1-4 60 **D**

Compared with the group II elements, the first row transition metals tend to be

A softer and form fewer coloured compounds.
B softer and form ions with a wider range of charges.
C harder and form fewer coloured compounds.
D harder and form ions with a wider range of charges.

Z1-5 60 **D**

The electronic structures of the atoms of five elements are given below.

Element	*Electronic structure*
I	$1s^2 2s^2 2p^6 3s^2$
II	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
III	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$
IV	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

Which of these elements is metallic and has a tendency to show a range of oxidation states in its compounds?

A I **B** II **C** III **D** IV

Z1-6 80* **C**

The electronic configuration of an iron atom is

A $1s^2 2s^2 2p^6 3s^2 3p^4$.
B $1s^2 2s^2 2p^6 3s^2 3p^6$.
C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$.
D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$.

Z1-7 60 **C**

The largest oxidation state found in compounds of the element with an atomic number of 23 is likely to be

A 3. **B** 4. **C** 5. **D** 7.

Z1-8 70 **D**

A suspension of solid MnO_2 in dilute aqueous acid can be converted to a solution of manganese(II) ions by

A raising $[H^+]$.
B lowering $[H^+]$.
C adding a strong oxidizing agent.
D adding a strong reducing agent.

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Z1-9 40 **A**

Chromate ions in aqueous solution can be converted to dichromate ions by

A increasing $[H^+]$.
B decreasing $[H^+]$.
C adding a strong oxidizing agent.
D adding a strong reducing agent.

Z1-10 40 **C**

A major product formed when crystals of potassium dichromate are shaken with concentrated sodium hydroxide solution is

A Cr^{3+}. **B** Cr_2O_3. **C** CrO_4^{2-}. **D** $Cr(OH)_6$.

Z2 Metal complexes

Z2a Ligands

Z2a-1 80 **A**

A ligand is best described as a

A molecule or ion which bonds to a central ion.
B complex ion containing neutral molecules surrounding a central ion.
C species containing ions surrounding an oppositely charged central ion.
D complex ion containing molecules attached to a cation at more than one point.

Z2a-2 20 **C**

Which of the following species is **least** likely to act as a ligand?

A PH_3
B CN^-
C NH_4^+
D $NH_2CH_2CH_2NH_2$

Z2a-3 60 **C**

The ligand in $Fe(NO_3)_3.6H_2O$ is the species

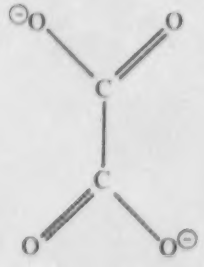
A Fe^{3+}. **B** NO_3^-. **C** H_2O. **D** $Fe(NO_3)_3$.

Z2a-4 40 **D**

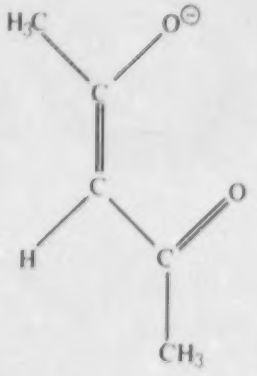
Which of the following species could **not** act as a chelating ligand?

A $NH_2CH_2CH_2NH_2$

B



C



D $CH_3CH_2CH_2CH_2S^-$

Z2b Formulae

Z2b-1 50 **D**

Which of the following complexes contains the Ni^{2+} ion?

A $Ni(CN)_4^{4-}$
B $Ni(NH_3)_2Br_3$
C $Ni(NH_2CH_2CH_2NH_2)_2Cl_2^{2+}$
D $Ni(NH_3)_2Cl_2$

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Z2b-2 80 D

The acetylacetonate anion ($acac^-$) forms a non-polar complex with Ni^{2+} ions. The most likely empirical formula for this complex is

A $Ni(acac)_6^{4-}$.
B $Ni(acac)_3$.
C $Ni(acac)_3^{2-}$.
D $Ni(acac)_2$.

Z2b-3 60 E

Which of the following is the most likely formula for an iron(III) complex with the oxalate anion ($^-OOCCOO^-$)?

A $Fe(Ox)_3$
B $Fe(Ox)^{3+}$
C $Fe(Ox)_3^{3+}$
D $Fe(Ox)_2^{3+}$
E $Fe(Ox)_3^{3-}$

Z2c Ion-dipole bonds

Z2c-1 70 A

Which one of the following kinds of bonds exists between the copper and nitrogen atoms in the $Cu(NH_3)_4^{2+}$ complex?

A ion-dipole
B ionic
C covalent
D hydrogen

Z2c-2 30 C

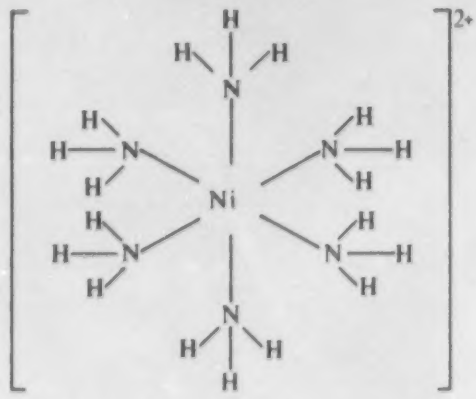
Which one of the following species contains ion-dipole bonds?

A $CuCl_4^{2-}$
B NH_4^+
C $Ag(NH_3)_2^+$
D NaCl
E HF

Z2c-3 80 D

Which of the following best represents the structural formula of the complex $Ni(NH_3)_6^{2+}$?

A



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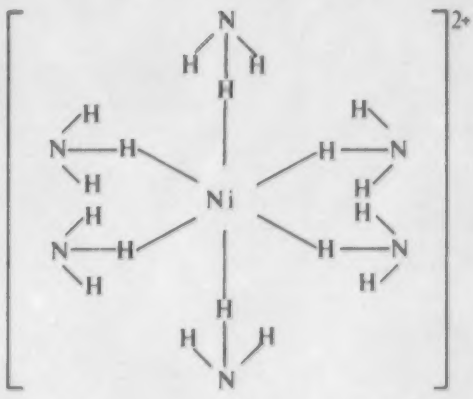
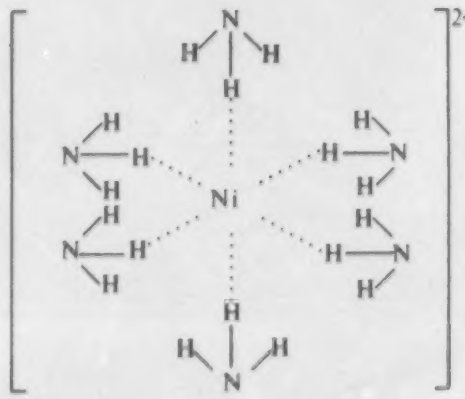
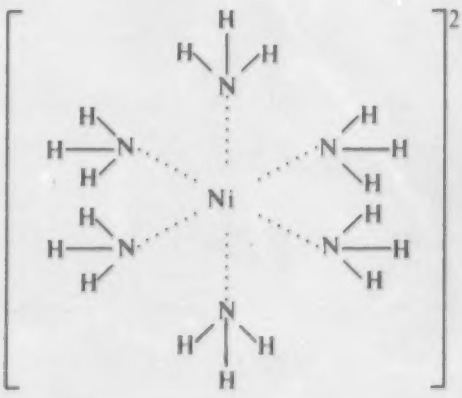


B



D



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Z2c-4 The bond between Al^{3+} ions and H_2O molecules in the compound $Al(H_2O)_6Cl_3$ results from

40

C

A ion-dipole attraction between Al^{3+} ions and hydrogen atoms in H_2O.

B sharing of electron pairs in H_2O molecules with Al^{3+} ions.

C attraction between Al^{3+} ions and oxygen atoms in H_2O molecules.

D hydrogen bonding between hydrogen atoms in H_2O molecules and Al^{3+} ions.

Z2c-5 The Cu^{2+} ions in a solution of copper(II) sulfate are

50

B

A involved in ion-dipole bonding to the hydrogen atoms of water molecules.

B electrostatically attracted to the oxygen atoms of water molecules.

C attracted to nearby water molecules by dispersion forces only.

D bonded to negatively charged sulfate groups.

Z2d Solubility

Z2d-1 Crystals of $Ni(NH_3)_6SO_4$ would be likely to dissolve in

40

D

A ethanol and be precipitated by the addition of water.

B water and be precipitated by the addition of benzene.

C chloroform and be precipitated by the addition of water.

D water and be precipitated by the addition of ethanol.

Z2d-2 Which of the following compounds is likely to be **least** soluble in water?

70

A

A $Cu(acac)_2$

B $Cu(en)_2SO_4$

C $Cu(NH_3)_4SO_4.H_2O$

D $(NH_4)_2CuCl_4$

Z2d-3 The compound $Cr(NH_3)_6SO_4$ is likely to be most soluble in

50

A

A water.

B ethanol.

C carbon tetrachloride.

D benzene.

Z2e Stability

Z2e-1 Consider the following reactions:

60

A

$Ag^+ + 2Cl^- \rightleftharpoons AgCl_2^-$ $\quad K_{st} = 1{\cdot}1 \times 10^5$

$Ag^+ + 2CN^- \rightleftharpoons Ag(CN)_2^-$ $\quad K_{st} = 1{\cdot}0 \times 10^{21}$

$Ag^+ + 2S_2O_3^{2-} \rightleftharpoons Ag(S_2O_3)_2^{3-}$ $\quad K_{st} = 1{\cdot}0 \times 10^{13}$

$Ag^+ + 2NH_3 \rightleftharpoons Ag(NH_3)_2^+$ $\quad K_{st} = 1{\cdot}6 \times 10^7$

Which of the following statements is correct?

A $Ag(S_2O_3)_2^{3-}$ would be the predominant complex in a solution formed by mixing 2 mol of $S_2O_3^{2-}(aq)$ with 1 mol of $Ag(NH_3)_2^+(aq)$.

B $AgCl_2^-$ would be the predominant complex in a solution formed by mixing 2 mol of $Cl^-(aq)$ with 1 mol of $Ag(S_2O_3)_2^{3-}(aq)$.

C $Ag(NH_3)_2^+$ would be the predominant complex in a solution formed by mixing 2 mol of $NH_3(aq)$ with 1 mol of $Ag(CN)_2^-(aq)$.

D $AgCl_2^-$ would be the predominant complex in a solution formed by mixing 2 mol of $CN^-(aq)$ with 1 mol of $AgCl_2^-(aq)$.

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Z3 Metal hydrides

Z3-1 40 **A**

Which of the following hydrides melts at the highest temperature?

A MgH_2 **B** SiH_4 **C** NH_3 **D** HCl

Z3-2 30* **E**

Which of the following hydrides acts as the strongest base when dissolved in water?

A H_2S **B** NH_3 **C** PH_3 **D** HCl **E** NaH

Z3-3 60 **D**

In which case do all members of the following groups of hydrides dissolve in water forming basic solutions?

A H_2S, PH_3, CH_4
B SiH_4, PH_3, H_2S
C AlH_3, NH_3, HCl
D NaH, AlH_3, NH_3

Z3-4 80* **C**

Sodium hydride, NaH, reacts with water to give

A Na^+ and OH^-.
B Na^+ and H^-.
C Na^+, OH^- and H_2.
D Na^+, OH^- and O_2.

Z3-5 40 **D**

When magnesium hydride, MgH_2, is added to water the most abundant species **in solution** is

A H^+. **B** Mg^{2+}. **C** H_2. **D** OH^-. **E** H^-.

Z3-6 30 **B**

A colourless crystalline solid reacts with water producing a gas and a basic solution. The solid could be

A Na_2O. **B** MgH_2. **C** Al_2O_3. **D** P_4O_{10}.

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The next three items refer to the following information

Some properties of 5 different substances are given in the table below.

Substance	Electrical conductivity of the solid	Electrical conductivity of the liquid	Reaction with water	Boiling temperature / °C
I	poor	poor	Vigorous reaction; hydrogen chloride produced	150 (sublimes)
II	poor	good	Vigorous reaction; hydrogen and an alkaline solution produced	700
III	good	good	Vigorous reaction; hydrogen and an alkaline solution produced	750
IV	poor	good	Vigorous reaction; no gas evolved, but a sparingly soluble white solid produced	2500
V	poor	good	Dissolves readily to give a conducting solution. No gas evolved.	1500

Which of the substances whose properties are tabulated above illustrate the following classes of substance?

Z3-7 an ionic hydride
40
B
A I **B** II **C** III **D** IV **E** V

Z3-8 a covalent compound
70
A
A I **B** II **C** III **D** IV **E** V

Z3-9 an element
40
C
A I **B** II **C** III **D** IV **E** V

Z4 Metal oxides

Z4a Preparation

Z4a-1 Which one of the following metals is most likely to form a compound containing the O^{2-} ion when burnt in a plentiful supply of oxygen?
70
B
A potassium **B** magnesium **C** sodium **D** caesium

Z4a-2 When magnesium burns in oxygen, the combustion product is
40
B
A a mixture of magnesium oxide and magnesium superoxide.
B an ionic solid containing O^{2-} ions.
C MgO, MgO_2 or $Mg(O_2)_2$, depending upon the amount of oxygen present during the reaction.
D a mixture of magnesium peroxide and magnesium superoxide.

Z4a-3 The oxide formed when sodium metal burns in a plentiful supply of air is best represented by the formula
20*
D
A Na_2O. **B** NaO. **C** NaO_2. **D** Na_2O_2.

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Z4a-4 80* **C**

Sodium metal rapidly tarnishes in dry air, forming an oxide. To prevent this, the metal is usually stored under

A ethanol.
B distilled water.
C paraffin oil.
D concentrated sulfuric acid.

Z4a-5 50 **A**

The strong base potassium peroxide can be formed by heating potassium in oxygen.

The empirical formula of potassium peroxide is

A KO. **B** K_2O. **C** KO_2. **D** K_2O_3.

Z4a-6 30 **C**

The group I metals potassium, rubidium and caesium burn in excess air to form compounds containing the superoxide ion. The formula for the superoxide ion is

A O^{2-}. **B** O_2^{2-}. **C** O_2^-. **D** O^-.

Z4b Properties

Z4b-1 40 **C**

Sodium oxide (Na_2O) is added to excess cold water. Which one of the following would occur?

A no appreciable reaction
B reaction to yield hydrogen and an aqueous solution of sodium hydroxide
C reaction to yield an aqueous solution of sodium hydroxide
D reaction to yield oxygen and an aqueous solution of sodium hydroxide
E reaction to yield hydrogen and an aqueous solution of sodium peroxide

Z4b-2 50 **A**

The oxide formed when magnesium burns in air reacts with

A $H^+(aq)$ but not with $OH^-(aq)$.
B $OH^-(aq)$ but not with $H^+(aq)$.
C both $H^+(aq)$ and $OH^-(aq)$.
D neither $H^+(aq)$ nor $OH^-(aq)$.

Z4b-3 60 **B**

An oxide which is not appreciably soluble in water dissolves in both hydrochloric acid and in sodium hydroxide solution.

Of the following, the oxide could be

A P_4O_{10}. **B** Al_2O_3. **C** MgO. **D** Cl_2O_7.

Z4b-4 70* **C**

Alumina, Al_2O_3, is the abrasive component of toothpaste. Which of the following statements about its chemical properties is correct?

Alumina reacts with

A hydrochloric acid but not with sodium hydroxide solution.
B sodium hydroxide solution but not with hydrochloric acid.
C both hydrochloric acid and sodium hydroxide solution.
D neither hydrochloric acid nor sodium hydroxide solution.

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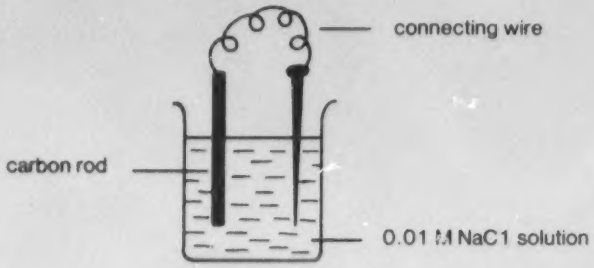
Z5 Corrosion

Z5-1 30* **B**

An iron nail and a carbon rod were partially immersed in a beaker containing 0.01 M sodium chloride solution. The nail and the rod were then connected by a wire as shown.



Which of the following would be expected to occur to the greatest extent?

A Cl_2 gas is produced at the carbon rod.
B OH^- ions are produced at the carbon rod.
C O_2 gas is produced at the carbon rod.
D H_2 gas is produced at the nail.

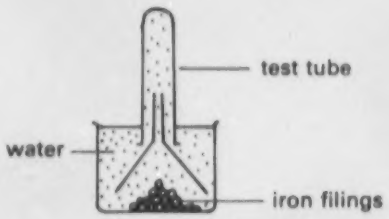
Z5-2 40 **C**

Which one of the following processes is **not** likely to occur as iron corrodes in a damp environment?

A conversion of Fe^{2+} to Fe^{3+}
B reduction of O_2
C evolution of H_2 gas
D dehydration of $Fe(OH)_3$

Z5-3 20* **C**

A test tube filled with water was inverted over iron filings in a beaker of water, as illustrated in the diagram.



Which one of the following will occur if the system is left for several days?

A The test tube would be filled with oxygen gas.
B The test tube would be filled with hydrogen gas.
C The pH of the liquid would have increased.
D There would be no change in the appearance of the iron filings.

The next three items refer to the following information

The underground pipeline bringing natural gas from Gippsland to Melbourne must pass through salty marshlands. Iron pipes are particularly susceptible to corrosion in the environment.

Z5-4 50 **C**

The overall corrosion reaction involves

A reduction of the iron.
B reaction of the iron with the dissolved salt.
C reaction of the iron with the dissolved oxygen.
D reaction of the iron with acid from dissolved carbon dioxide.

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Z5-5
40
D

The corrosion process occurs in several steps.

Which of the following is **not** likely to be occurring as the iron corrodes?

A $Fe + O_2 + 2H_2O \rightarrow Fe^{2+} + 4OH^-$

B $4Fe^{2+} + O_2 + 2H_2O + 8OH^- \rightarrow 4Fe(OH)_3$

C $2Fe(OH)_3 \rightarrow Fe_2O_3.2H_2O + H_2O$

D $4Fe(OH)_3 \rightarrow 4Fe(OH)_2 + O_2 + 2H_2O$

Z5-6
50
D

By referring to the E^0 values below, select which one of the following methods would be least successful in reducing the corrosion of the iron.

$E^0_{Fe^{2+},Fe} = -0{\cdot}44\,V$; $E^0_{Cu^{2+},Cu} = +0{\cdot}34\,V$; $E^0_{Zn^{2+},Zn} = -0{\cdot}76\,V$

A completely plating the pipes with a coating of zinc

B attaching a piece of buried zinc metal to the pipe with an iron wire

C completely plating the pipes with a coating of copper

D attaching a piece of buried copper metal to the pipe with an iron wire

Z5-7
60
D

Steel will corrode in the presence of oxygen and water, unless precautionary measures are taken.

Which one of the following does **not** occur in the formation of rust in a **damp** environment?

A the oxidation of Fe to Fe^{2+} with the corresponding reduction of oxygen to OH^-

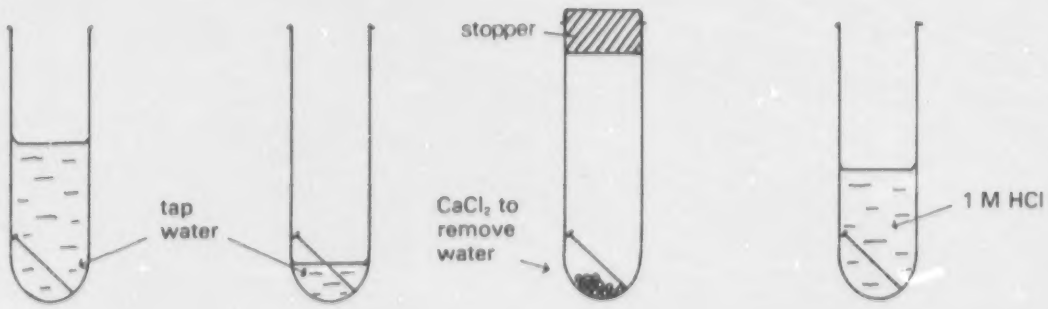
B the oxidation of Fe^{2+} to Fe^{3+} by reaction with water and oxygen

C the formation of $Fe(OH)_3$

D the dehydration of $Fe(OH)_3$ to Fe_2O_3

Z5-8
10
A,B,D

In an experiment to investigate corrosion, iron nails were placed in different environments, as shown below.



After several months, in which **one or more** of the environments would corrosion be likely to be observed?

A I **B** II **C** III **D** IV

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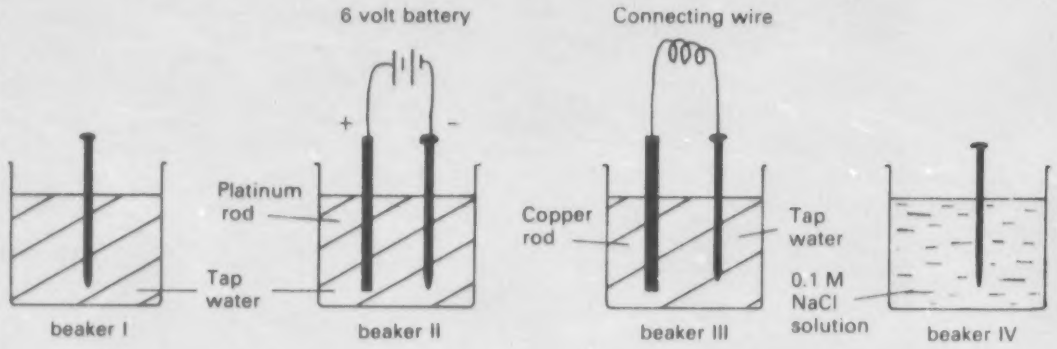
Z5-9 10 **B,C**

Four iron nails were arranged in beakers as shown:

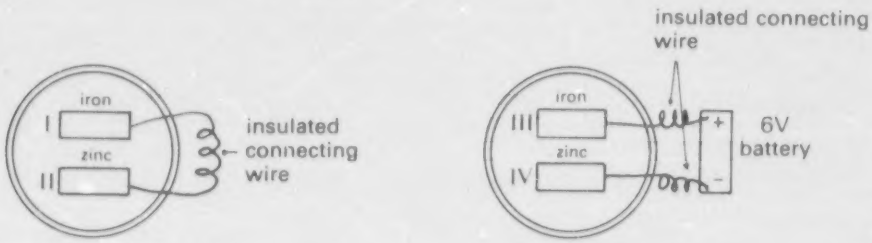


In which **one or more** of the following beakers is corrosion likely to occur more rapidly than in beaker I?

A II **B** III **C** IV

Z5-10 20* **B**

Metal plates were placed in two watch glasses containing a dilute aqueous solution of sodium chloride and phenolphthalein, as shown.



The phenolphthalein would initially turn pink in the regions labelled

A I and III. **C** II and III.
B I and IV. **D** II and IV.

Z5-11 60 **B**

Zinc blocks buried in the soil are often attached at regular intervals to steel pipe lines. The purpose of the zinc blocks is to

A reduce the Fe^{2+} ions formed to Fe.
B be oxidized preferentially before the Fe.
C promote formation of a protective film of Fe_2O_3 on the pipe line.
D preferentially react with any reducing agent near the pipe line.

Z5-12 40* **C**

One way to protect iron from corrosion is to apply a coating of nickel to the metal by electrolysis. Corrosion is prevented because

(given $E^0_{Ni^{2+}, Ni} = -0.23$ V, $E^0_{Fe^{2+}, Fe} = -0.41$ V)

A nickel is a stronger reductant than iron, and is preferentially oxidized.
B nickel accepts electrons from the iron, preventing oxidation.
C the thin coating of nickel prevents oxygen from reacting with the iron.
D iron and nickel form an alloy steel which is particularly resistant to corrosion.

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Z5-13 60 **C**

Plumbers must be careful not to weld together two dissimilar metals in hot water systems because

A the metal with the more positive E^0 value would be oxidized.
B an elastic junction is needed to allow for the different thermal expansion of the metals.
C the more easily oxidized metal would transfer electrons to the other metal.
D alloys formed between dissimilar metals are weaker and more prone to corrosion.
E the EMF produced by such a connection would decompose water into its elements.

Z5-14 70 **C**

Freshly prepared aluminium filings react more vigorously with water than do freshly prepared iron filings, yet pots and pans are more likely to be made of aluminium than iron.
This is because

A aluminium is less likely to react than iron.
B iron rapidly forms an oxide coating, whereas aluminium forms such a coating only slowly.
C aluminium is covered by a uniform protective oxide film, whereas iron does not form such a uniform film.
D aluminium is not oxidized as rapidly, at high temperatures, as is iron.

Z6 Metal hydroxides

Z6-1 70* **C**

Which of the equations below represents the reaction of sodium metal with water?

A $Na + H_2O \rightarrow NaO + H_2$
B $2Na + H_2O \rightarrow Na_2O + H_2$
C $2Na + 2H_2O \rightarrow 2NaOH + H_2$
D $Na + 2H_2O \rightarrow Na(OH)_2 + H_2O$

Z6-2 60 **C**

Addition of a few drops of a dilute sodium hydroxide solution to an aqueous solution produces a green gelatinous precipitate which does not dissolve when further base is added. On standing the precipitate becomes red-brown in colour.

The aqueous solution could contain

A $FeCl_3$. **B** $CrCl_3$. **C** $FeSO_4$. **D** $NiCl_2$.

Z6-3 60 **A**

Magnesium hydroxide, $Mg(OH)_2$,

A reacts readily with dilute acid to give Mg^{2+} ions in solution, but does not react readily with dilute alkali.
B reacts readily with acid to give Mg^{2+} ions in solution and with dilute alkali to give MgO_2^{2-} ions.
C does not react with dilute acid, but reacts with dilute alkali to give $Mg(OH)_4^{2-}$ ions.
D reacts readily with acid to give Mg^{2+} ions in solution and with dilute alkali to give $Mg(OH)_4^{2-}$ ions.

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The next three items refer to the following table

Salt solution	Result if dilute ammonia solution added	Result if excess ammonia solution added	Result if dilute sodium hydroxide solution added	Result if excess sodium hydroxide solution added
YCl_2(aq)	precipitate forms	precipitate dissolves	precipitate forms	precipitate dissolves
QCl(aq)	no precipitate	no precipitate	no precipitate	no precipitate
RNO_3(aq)	precipitate forms	precipitate dissolves	precipitate forms	precipitate remains

Z6-4 Y in YCl_2 could be

10* **B**

A Ca^{2+}. **B** Zn^{2+}. **C** Mg^{2+}. **D** Fe^{2+}.

Z6-5 Q in QCl could be

50 **D**

A NH_4^+ only. **B** K^+ only. **C** K^+ or H^+ only. **D** K^+ or H^+ or NH_4^+.

Z6-6 R in RNO_3 could be

70 **B**

A H^+. **B** Ag^+. **C** Na^+. **D** NH_4^+.

Z6-7 Excess dilute sodium hydroxide solution is slowly added to each of the following solutions.

30 **C,D**

In which **two** cases does a precipitate form which subsequently dissolves?

A iron(II) sulfate
B magnesium sulfate
C zinc sulfate
D aluminium sulfate
E potassium sulfate

Z6-8 Which one of the following metal hydroxides does **not** react with excess hydroxide ion?

30 **C**

A $Cu(OH)_2$ **B** $Zn(OH)_2$ **C** $Fe(OH)_3$ **D** $Al(OH)_3$

Z6-9 A white precipitate of $Al(OH)_3$ is formed when excess NH_3 solution is added to a solution of an Al^{3+} salt.

30 **A**

The precipitate.

A dissolves on addition of either sodium hydroxide solution or hydrochloric acid.
B dissolves on addition of sodium hydroxide solution, but not if hydrochloric acid is added.
C dissolves on addition of hydrochloric acid, but not if sodium hydroxide solution is added.
D does not dissolve on addition of either sodium hydroxide solution or hydrochloric acid.

Z7 Occurrence of metals and metal ores

Z7-1 The most abundant metal in the earth's crust is

30 **B**

A copper. **C** zinc.
B aluminium. **D** iron.

Z7-2 Which one of the following metals is **not** usually found as an oxide ore in nature?

80 **B**

A iron **C** aluminium
B calcium **D** uranium

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Z7-3 Which of the following metals is most likely to be found naturally as an oxide ore?

40

C

A calcium
B magnesium
C tin
D sodium

Z7-4 The alkaline earth metals occur naturally as

40

A

A metal halides.
B metal oxides.
C metal sulfides.
D free metals.

Z7-5 Metals are prepared commercially by extraction from their ores. A major constituent of a commercially extractable ore would be

30

D

A UF_6. B FeO. C $AgNO_3$. D PbS. E TiO_4.

Z7-6 Which one of the following factors could be important in determining if a mineral deposit is an ore body?

80

D

A geographical location of the mineral deposit
B concentration of metal in the mineral deposit
C selling price of the metal
D all of the above

Z8 Ease of extraction of metals

Z8-1 Which of the following extraction processes would require the **least** energy for the formation of one mole of metal?

30

A

A Ag from Ag_2S
B Fe from Fe_2O_3
C Mg from $MgCO_3$
D Al from Al_2O_3
E Na from NaCl

Z8-2 A metal can often be isolated by heating a mixture of the metal oxide with carbon.

30

A

In a particular experiment, samples of oxides of copper, sodium, iron and aluminium were mixed with powdered carbon and heated in an oven. As the temperature of the mixture increased, the first metal to appear would be

A copper. B sodium. C iron. D aluminium.

Z8-3 Which one of the following oxides **cannot** be smelted with coke under the conditions found in a blast furnace to yield the metal?

50

B

A Ag_2O B Al_2O_3 C PbO D CuO

Z8-4 Which one of the following metal oxides could **not** be reduced to the metal using a blowpipe, Bunsen flame and charcoal block?

80

B

A Fe_2O_3 B Al_2O_3 C PbO D CuO

Z8-5 In which of the following alternatives are metals listed in order of increasing **ease** of extraction from their ores?

20

B

A Fe, Al, Cu
B Al, Fe, Cu
C Al, Cu, Fe
D Cu, Al, Fe
E Cu, Fe, Al

Z8-6 In which of the following lists are the metals copper, aluminium and iron listed in order of increasing strength as reducing agents?

40

A

A copper, iron, aluminium
B iron, copper, aluminium
C aluminium, iron, copper
D aluminium, copper, iron

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Z8-7
30
C

In the refining of copper, the electrolyte used is acidified copper sulfate, whereas in the refining of aluminium the electrolyte is molten cryolite (Na_3AlF_6) in which alumina (Al_2O_3) has been dissolved.

The reason for the use of different electrolytes is that

A Al^{3+} ions do not dissolve in water, whereas Cu^{2+} ions do dissolve in water.

B Al^{3+} ions can only be reduced at high temperature, whereas Cu^{2+} ions are reduced at low temperatures.

C Al^{3+} ions are not reduced in aqueous solutions, whereas Cu^{2+} ions are reduced in aqueous solutions.

D Al^{3+} ions react to form $Al(H_2O)_6^{3+}$ complex ions in aqueous solution, whereas Cu^{2+} ions do not form similar complex ions.

Z8-8
60
C

It is predicted that more energy is required per mole in the refining of molten alumina than in the refining of molten iron ore because

A the refining of alumina is an electrochemical process, whereas that of iron ore is a thermal process.

B alumina has a much higher melting temperature than iron ore.

C alumina is more difficult to reduce to aluminium than iron oxide is to iron.

D aluminium has a much higher melting temperature than iron.

Z8-9
50
A

Iron can be extracted from its ores in the blast furnace by reduction of the ores with CO gas. Since potassium **cannot** be extracted this way it is likely that potassium

A is a much stronger reductant than iron.

B ores melt at higher temperatures than iron ores.

C melts at a higher temperature than iron.

D is a much stronger oxidant than iron.

Z9 Extraction techniques

Z9a Mineral dressing (froth flotation)

Z9a-1
80
D

One stage in the production of metals from their ores is known as mineral dressing. The purpose of mineral dressing is

A to increase the surface area of the mineral particles in order to make reduction to the metal easier.

B the flotation and collection of the insoluble impurities that occur with the mineral.

C aeration of the crushed ore in order to convert the sulfides into oxides for easier reduction.

D the concentration of a mineral by its separation from other minerals and worthless material.

Z9a-2
80
A

The process of mineral dressing involves

A sorting of minerals from other material.

B conversion of metal sulfides to the metal oxide.

C formation of a slag to remove impurities.

D extraction of a metal from a mineral.

Z9a-3
90
C

In the process of froth flotation using xanthate as a collector, mineral particles become

A water attracting by adsorption of xanthate ions.

B water attracting by adsorption of a frother.

C water repellent by adsorption of xanthate ions.

D water repellent by adsorption of a frother.

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Z9a-4 60 **B**

Kerosene will act as a collector for some minerals, but xanthates are used in industry. One reason for this is because kerosene

A is non polar and is insoluble in water.
B does not selectively collect mineral particles.
C does not produce a stable head of froth.
D will only float particles of a certain size.

Z9a-5 80 **C**

Which of the following minerals is most likely to be separated from impurities by flotation using a xanthate as a collector?

A silica (SiO_2)
B malachite ($Cu_3(OH)_2(CO_3)_2$)
C galena (PbS)
D cassiterite (SnO_2)

Z9b Roasting

Z9b-1 80 **B**

Sulfide ores are usually roasted before the ore is reduced with carbon or hydrogen. This is mainly because

A any sulfur present in the ore would react to form the toxic gases CS_2 or H_2S.
B sulfides cannot be effectively reduced by carbon or hydrogen.
C SO_2 gas is needed to manufacture sulfuric acid used in the process.
D all metal in the ore must have the same oxidation number for efficient processing.

Z9b-2 80 **A**

Mineral concentrates containing metal sulfides are usually roasted. In this process the concentrates are heated in the presence of

A air.
B pure hydrogen sulfide.
C carbon dioxide.
D carbon monoxide.

Z9c Leaching

Z9c-1 60 **C**

Leaching is a process employed in hydrometallurgical plants in which

A a metal ion is selectively precipitated by the formation of a metal complex.
B metal ions are separated on the basis of their different solubilities in organic liquids.
C a solution is prepared containing the metal ion to be recovered.
D selective separation of the metal ions in a solution is achieved by adjusting pH.

Z9d Solvent extraction

Z9d-1 50 **B**

Which one of the following **must** be a property of organic liquids used to purify solutions of metal ions by solvent extraction?

A They have a lower density than water.
B They do not dissolve in water.
C They have a higher density than water.
D They are more polar than water.

Z9d-2 60 **D**

Naphthenic acid extracts metal ions from aqueous solution because

A the ions participate in hydrogen bonding with the acid molecules.
B metal ions dissolve readily in non-polar solvents.
C the ions form ion-dipole bonds with neighbouring acid molecules.
D the ions form weak bonds with naphthenate anions.

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Z9d-3 70 **A**

Control of water pollution is easier in pyrometallurgical plants than in hydrometallurgical plants. This is because

A the water in pyrometallurgical plants is mainly used for cooling and contamination is small.

B contaminants in water from pyrometallurgical plants tend to be heavy metals and are more easily precipitated.

C impurities tend to be concentrated by the recycling processes used in hydrometallurgical plants.

D the presence of organic liquids in water from hydrometallurgical plants causes high concentrations of metal ions.

Z9e Electrowinning

Z9e-1 60 **D**

The process of electrowinning involves electrolytic

A purification of a piece of impure metal, which acts as an anode in a cell.

B purification of a piece of impure metal, which acts as a cathode in a cell.

C deposition of metal ions from solution on an anode in a cell.

D deposition of metal ions from solution on a cathode in a cell.

Z9e-2 70 **C**

If m_1 is the mass of a metal obtained by electrolysis and m_2 is the mass expected on the basis of Faraday's Law, the current efficiency is the ratio

A $\frac{m_2}{m_1} \times 100.$

B $\frac{m_2 - m_1}{m_2} \times 100.$

C $\frac{m_1}{m_2} \times 100.$

D $\frac{m_2 - m_1}{m_1} \times 100.$

Z9e-3 30 **A**

A current of 1·1 A is passed through a cell containing a solution of zinc(II) sulfate for 1 hour. If 0·90 g of metal were deposited, the current efficiency would be (given $F = 96487$ C mol^{-1}; A_r, Zn = 65·4)

A $\frac{96487 \times 2 \times 0{\cdot}90 \times 100}{1{\cdot}1 \times 60 \times 60 \times 65{\cdot}4}$ %.

B $\frac{96487 \times 0{\cdot}90 \times 100}{1{\cdot}1 \times 60 \times 60 \times 2 \times 65{\cdot}4}$ %.

C $\frac{1{\cdot}1 \times 60 \times 60 \times 0{\cdot}90 \times 100}{96487 \times 65{\cdot}4}$ %.

D $\frac{96487 \times 0{\cdot}90 \times 100}{1{\cdot}1 \times 60 \times 60 \times 65{\cdot}4}$ %.

E $\frac{1{\cdot}1 \times 60 \times 60 \times 65{\cdot}4 \times 100}{96487 \times 2 \times 0{\cdot}90}$ %.

Z10 Iron extraction

Z10a Methods

Z10a-1 30 **B**

Which one of the following procedures could not be used to convert iron ore to iron?

A electrolysis of the molten ore

B passage of CO_2 gas over the ore at high temperatures

C passage of H_2 gas over the ore at high temperatures

D heating a mixture of carbon and iron ore

Z10a-2 30 **F**

In the blast furnace, iron oxides are reduced to metallic iron. The reducing agent is

A air. **B** coke. **C** SiO_2. **D** limestone. **E** CO_2. **F** CO.

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Z10a-3 60* C

Iron ore is admitted at the top of a blast furnace. Which of the following must also be added to ensure the successful operation of the furnace?

A limestone and sand
B sand and coke
C limestone and coke
D limestone, sand and coke

Z10a-4 50 C

Which of the following processes would **not** occur in a blast furnace?

A Coke is added as a source of carbon monoxide.
B Carbon monoxide reduces Fe_2O_3 to Fe.
C Impurities in the ore combine with carbon monoxide to form a slag.
D The molten pig iron collects at the **bottom** of the furnace.

Z10a-5 60 A

Which one of the following reactions is **least** likely to occur in a blast furnace?

A $3FeO + CO_2 \rightarrow Fe_3O_4 + CO$
B $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
C $CaCO_3 \rightarrow CaO + CO_2$
D $C + CO_2 \rightarrow 2CO$

Z10a-6 70 D

Haematite is reduced in the blast furnace to iron metal. Successive oxides occurring in this process could be represented as

A FeO, Fe_2O_3, Fe_3O_4.
B Fe_3O_4, FeO, Fe_2O_3.
C Fe_2O_3, FeO, Fe_3O_4.
D Fe_2O_3, Fe_3O_4, FeO.

Z10a-7 50 A

Coke has several functions in the blast furnace. Which of the following is **not** one of its functions?

A forming a slag with impurities
B keeping the contents of the furnace porous
C acting as a reductant
D acting as a source of heat when oxidized

Z10a-8 50 A

The material(s) specifically added to the blast furnace charge in order to form a slag is (are)

A limestone.
B sand.
C limestone and coke.
D limestone and sand.
E limestone, sand and coke.

Z10a-9 80 D

Limestone and other solid feed materials are admitted at the top of a blast furnace during the smelting of iron ore. The main purpose of the limestone is to

A act as a source of carbon dioxide.
B act as a catalyst in the reduction reaction.
C reduce iron oxides to iron metal.
D react with impurities to form a slag.

Z10b Types of iron

Z10b-1 60 D

Cast iron is a type of

A sponge iron.
B wrought iron.
C steel.
D pig iron.

Z10b-2 70 B

Small quantities of metal can be extracted from some oxides using a charcoal block, a Bunsen burner and a blowpipe. The extraction of iron by this method occurs at temperatures below the melting temperature of iron.

The product is best described as

A pig iron.
B sponge iron.
C wrought iron.
D cast iron.

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Z10b-3 | Wrought iron may be prepared from sponge iron by
90
B

A heating in the presence of coke.
B rolling at high temperatures.
C alloying with controlled quantities of other metals.
D blowing pure CO on the surface of the molten metal.

Z10b-4 | Compared to pig iron, wrought iron has a
70
C

A higher carbon content and is more ductile.
B higher carbon content and is less ductile.
C lower carbon content and is more ductile.
D lower carbon content and is less ductile.

Z11 Steel manufacture

Z11-1 | The chemical changes occurring to iron in a blast furnace and to impurities in iron in a steel making furnace may be classified as, respectively,
60
D

A oxidation and oxidation.
B oxidation and reduction.
C reduction and reduction.
D reduction and oxidation.

Z11-2 | Which of the following statements best describes the reaction conditions employed in iron making and steel making?
80
A

A Reducing conditions are used in iron making and oxidizing conditions are used in steel making.
B Oxidizing conditions are used in iron making and reducing conditions are used in steel making.
C Reducing conditions are used in both iron making and steel making.
D Oxidizing conditions are used in both iron making and steel making.

Z11-3 | Which of the lists below gives wrought iron, pig iron and steel in order of increasing carbon content?
20
B

A wrought iron, pig iron, steel
B wrought iron, steel, pig iron
C steel, wrought iron, pig iron
D steel, pig iron, wrought iron
E pig iron, wrought iron, steel
F pig iron, steel, wrought iron

Z11-4 | An integrated steelworks is **defined** as a steelworks in which
50
C

A there is a minimal loss of energy throughout the plant.
B the steel furnace is fed directly from the blast furnace.
C pig iron extraction, steel making and shaping operations are performed.
D the raw materials used are mined in the local area.

Z11-5 | Electrostatic precipitators are used in integrated steelworks in order to
60
A

A collect small particles of iron oxide in exhaust gases.
B reduce the emissions of sulfur dioxide to the atmosphere.
C remove finely divided particles from contaminated water.
D condense steam generated in the coke ovens during quenching.
E precipitate exhaust gases from the blast furnace.

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Z12 Copper extraction

Z12a Pyrometallurgical methods

Z12a-1 60 A

The stages in the industrial production of copper are, in order,

A flotation; roasting; electrolysis.
B roasting; electrolysis; flotation.
C electrolysis; roasting; flotation.
D roasting; flotation; electrolysis.

Z12a-2 60 C

Which of the following is **not** a step in the industrial production of refined copper?

A the flotation of a copper ore
B the roasting of copper sulfide ores
C the heating of a mixture of copper oxide and coke in a furnace
D the electrolysis, using a copper anode, of an acidified copper sulfate solution

Z12a-3 70 B

The first stage in the extraction of copper from its sulfide ores is usually to

A roast the ore in the presence of air.
B concentrate the ore by flotation.
C melt the ore in the presence of silica.
D dissolve the ore in sulfuric acid solution.

Z12a-4 60 B

The first stage of convential copper smelting is to roast the concentrate in air. The product is called

A matte.
B calcines.
C blister copper.
D slag.

Z12a-5 90 B

When a copper sulfide ore is roasted to produce copper, the major gaseous product of the roasting process is

A SO_3. **B** SO_2. **C** S_8. **D** CO. **E** CO_2.

Z12a-6 50 D

Which one of the following processes does **not** usually occur in the pyrometallurgical production of copper from a sulfide ore?

A Silica is added to the calcines to produce slag.
B Iron reacts preferentially with oxygen in the converter.
C Cu_2S is reduced to copper metal in an air blow.
D Copper oxides are roasted in air.

Z12a-7 60 A

The copper concentrate obtained from flotation often contains about 30 % iron in the form of an iron sulfide. The majority of the iron is removed in conventional smelting by

A formation of iron oxide and extraction in a slag.
B reduction using carbon monoxide and separation in a slag.
C separation of the liquid iron and copper phases.
D electrolytic refining of the impure copper metal.
E oxidation and separation by solvent extraction.

Z12a-8 70 A

In the conventional smelting of copper, copper matte is transferred to a converter vessel where iron impurities are separated and removed in a slag. An important reason why iron separates from the copper in the converter is the greater affinity of

A iron for oxygen.
B copper for oxygen.
C iron for sulfur.
D copper for sulfur.

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Z12a-9
40
D

Silica is used as a purifying agent in the conventional copper smelting process. It is mainly used to remove

A aluminium.
B sulfur.
C phosphorus.
D iron.

Z12a-10
50
E

During conventional copper smelting, copper matte is transferred from the reverberatory furnace to the converter. The final product from the converter is mainly

A Cu_2S. B Cu_20. C CuS. D Cu0. E Cu.

Z12a-11
30
A

Wooden poles are often used to stir molten copper during the refining process. They are employed mainly because

A gases distilled from the poles reduce any copper oxide present.
B most common metals would melt in the high temperature conditions.
C the low thermal conductivity of wood permits stirring to be done manually.
D alloys are formed if other metals are present.

Z12a-12
80
D

The major pollutant from copper smelters is

A CO_2 gas.
B CO gas.
C copper oxide dust.
D SO_2 gas.
E H_2S gas.

Z12a-13
40
E

A gas which would be a suitable raw material for a sulfuric acid plant is most likely to be obtained from a

A blast furnace.
B flotation cell.
C electrowinning cell.
D steel making furnace.
E copper smelter.

Z12b Electrorefining

Z12b-1
30
A

Trace metal impurities present in the 'fire refined copper' produced in copper smelters may be removed by electrorefining.

During this process, metals that are more easily

A oxidized than copper will dissolve into solution.
B oxidized than copper will be deposited on the anode.
C reduced than copper will be deposited on the cathode.
D oxidized than copper will fall to the bottom of the cell.

Z12b-2
40
D

Which of the following metals is most likely to be found in the mud at the bottom of an electrolysis cell used for electrorefining copper?

A iron
B zinc
C nickel
D gold

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Z12c-1
70
D

Which of the lists below names processes used in hydrometallurgical extraction of copper in the sequence in which they are employed?

A solvent extraction, electrolysis, leaching
B solvent extraction, leaching, electrolysis
C leaching, electrolysis, solvent extraction
D leaching, solvent extraction, electrolysis

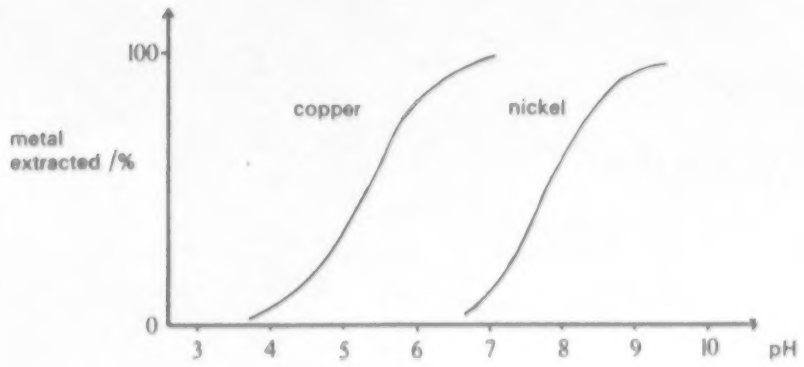
Z12c-2
80
C

Ammonia solutions can be used successfully to leach copper(II) oxide because

A ammonia reacts with impurities in the solution.
B ammonia solutions contain the strong leaching ion, NH_4^+.
C ammonia forms a complex with copper ions.
D the pH of the solution prevents precipitation of copper metal.

The next two items refer to the following information

The amount of metal extracted from an aqueous phase into naphthenic acid depends upon the pH of the aqueous phase. The graph below illustrates this relationship for copper and nickel.



Z12c-3
90
B

In order to **selectively** extract most of the copper ions from a solution containing copper and nickel ions into naphthenic acid, the pH of the solution should be

A 3. B 6. C 8. D 10.

Z12c-4
80
B

Copper ions extracted into naphthenic acid could be removed by addition of

A 1M sodium hydroxide solution.
B 1M sulfuric acid.
C 1M copper(II) sulfate solution.
D water.
E kerosene.

Z12c-5
40
D

Copper metal may be extracted from its ores by electrowinning. In this process, the ore is dissolved in sulfuric acid and the solution is electrolysed using electrodes made from lead and copper.
Which of the following would be the major product formed at the anode?

A copper metal
B Cu^{2+} ions
C hydrogen gas
D oxygen gas
E Pb^{2+} ions

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Z12c-6
40
B

If Fe^{2+} ions are present in solution during electrolytic winning of copper, the current efficiency is reduced. This is because the

A Fe^{2+} is reduced to iron metal at the anode of the cell.
B Fe^{2+} is oxidized to Fe^{3+} at one electrode and Fe^{3+} is reduced to Fe^{2+} at the other.
C Fe^{2+} is reduced to iron metal at the cathode of the cell.
D Fe^{2+} ions reduce Cu^{2+} to copper metal which is deposited at the bottom of the cell.
E Fe^{2+} is reduced to iron metal at one electrode and oxidized to Fe^{3+} at the other.

Z13 Nickel extraction

Z13-1
30
A

The gas used to convert nickel concentrate to a matte is usually

A air. B CO. C H_2. D H_2S. E SO_2.

Z13-2
40
D

The ores of copper and nickel are insoluble in water. The extraction of low concentrations of these metals can be achieved by forming a compound which is very soluble in water. Which of the following formulae represents one such soluble compound?

A $Cu(OH)_2$
B $Ni(OH)_2$
C $Ni(NH_3)_2(OH)_4$
D $Cu(NH_3)_4(OH)_2$

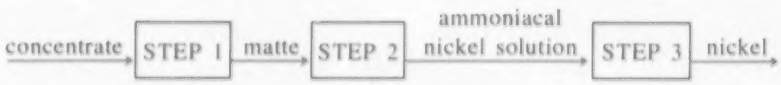
Z13-3
50
C

Which one of the following processes does **not** occur during the extraction of nickel from its ores in Australia?

A separation of impurities using hydrogen sulfide gas
B reduction of nickel ions using hydrogen gas
C formation of a slag by addition of silica
D leaching of metal ions into an ammonia solution

The next three items refer to the following information

One of the major methods for refining nickel concentrate is represented by the schematic diagram below.



Z13-4
50
A

The major gaseous product from the reaction occurring during Step 1 is

A SO_2. B CO_2. C H_2S. D CO.

Z13-5
30*
B

During Step 2 the nickel present in the matte is dissolved in water by the combined action of ammonia and

A SO_2. B O_2. C CO. D H_2.

Z13-6
20
D

Hydrogen sulfide gas is added to the ammoniacal solution of the nickel ore during Step 3. The main purpose of the gas is to

A reduce nickel ions to metallic nickel.
B neutralize excess ammonia, forming ammonium sulfide.
C reduce metal ion impurities to the metal.
D precipitate metal ion impurities as metal sulfides.

Z13-7
40
C

During the refining of nickel ore, Ni^{2+} ions present in an ammonia solution are reduced to metallic nickel by the action of

A CO(g). B H_2S(g). C H_2(g). D SO_2(g).

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Z13-8 | The major process employed for extracting nickel metal from nickel ore in Australia involves
30
B

A heating nickel concentrate in the presence of carbon and hydrogen gas.
B conversion of nickel ions to nickel metal using hydrogen gas.
C reduction of nickel ore by carbon monoxide at high temperatures.
D electrolytic deposition of metal ions on the cathode of a cell.

Z14 Zinc extraction

Z14-1 | Zinc is found as the mineral zinc blende in major deposits in New South Wales, Queensland and Tasmania. The mineral is usually converted to zinc by roasting zinc blende concentrate in hot air, followed by
60
B

A electrolysis of the molten product.
B electrolysis of a solution of the product in sulfuric acid.
C smelting the product with coke in a blast furnace.
D heating the product with sulfur dioxide gas in a furnace.

Z14-2 | In the electrolytic zinc process, as used in Tasmania and South Australia, the majority of the impurities are removed from the roasted concentrate by
30
D

A addition of silica to the molten material.
B injection of air in a reverberatory furnace.
C electrolysis of a solution of the material.
D precipitation from a solution of the material.

Z15 Aluminium extraction

Z15-1 | Aluminium is produced by electrolysis of alumina rather than by heating the ore with carbon or carbon monoxide because
40
A

A uneconomically high temperatures are needed for reduction of alumina using carbon or carbon monoxide.
B aluminium is very prone to oxidation at high temperatures, converting back to Al_2O_3.
C the melting temperature of aluminium is too high to permit economical extraction using carbon or carbon monoxide.
D Al^{3+} ions are more easily reduced than ions such as Fe^{3+} and Cu^{2+}.

Z15-2 | The major gaseous product from an aluminium cell is
40
C

A HF. B O_2. C CO_2. D F_2.

Z15-3 | Which of the following does **not** usually occur during the electrochemical extraction of aluminium metal?
30
C

A CO_2 is produced at the positive electrode.
B Alumina is dissolved in molten Na_3AlF_6.
C The cathode material is consumed and replaced at frequent intervals.
D Liquid aluminium is drawn off from the bottom of the cell.

Z15-4 | An electrolysis cell used for aluminium production is usually constructed with a
40
C

A steel mesh cathode and a carbon anode.
B carbon cathode and a steel mesh anode.
C carbon cathode and a carbon anode.
D carbon cathode and a lead anode.
E lead cathode and a carbon anode.

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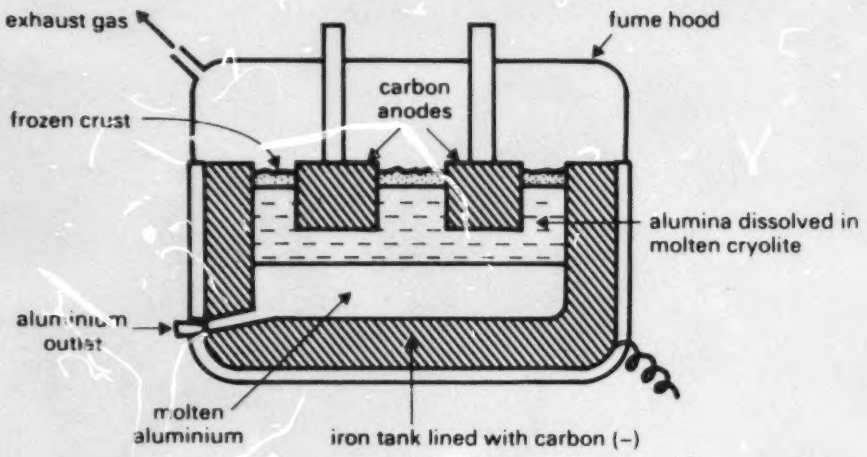
Z15-5
20
D

The diagram shows an electrolysis cell for the extraction of aluminium metal.



Which one of the following statements about this apparatus is correct?

A Carbon anodes are used because they are unreactive.

B At the cathode, alumina is reduced to aluminium and chlorine.

C The aluminium must be continually removed so that it does not interfere with the carbon cathode.

D Cryolite is used as a solvent because alumina reacts preferentially at the electrodes.

Z15-6
50
B

The anodes in the cells used for electrolytic extraction of aluminium from alumina are moveable. This is because

A overheating can occur due to the high current densities employed.

B the electrodes must be fed into the electrolyte since they are consumed during the electrolysis.

C it is essential to move the electrodes into regions where the anions tend to concentrate.

D the movement of electrodes is essential to break up the electrolytic crust of solid cryolite.

E the motion of the electrolyte lowers the overpotential for graphite electrodes in the cell.

Z15-7
50
D

Aluminium ($A_r = 27{\cdot}0$) is manufactured by the electrolysis of Al_2O_3 dissolved in melted cryolite. The reactions at the electrodes are:

$$Al_2O_3 + 6e^- \rightarrow 2Al + 3O^{2-}$$
$$C + 2O^{2-} \rightarrow CO_2 + 4e^-$$

What mass of aluminium would be expected from a cell operating at a current of 13000 A for 5 minutes (given $F = 96\,487$ C mol^{-1})?

A $\dfrac{13000 \times 5 \times 60 \times 3 \times 27{\cdot}0}{96487}$ g

B $\dfrac{96487 \times 3}{13000 \times 5 \times 60 \times 27{\cdot}0}$ g

C $\dfrac{13000 \times 5 \times 60 \times 96487 \times 27{\cdot}0}{3}$ g

D $\dfrac{13000 \times 5 \times 60 \times 27{\cdot}0}{96487 \times 3}$ g

E $\dfrac{13000 \times 5 \times 60 \times 27{\cdot}0}{96487}$ g

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Z15-8
50
C

The fluoride ion is a potential pollutant from aluminium smelters. The major source of the fluoride ion is the

A F_2 gas used to reduce Al^{3+} ions to the metal.
B F^- impurity in alumina used in electrolysis cells.
C AlF_6^{3-} ions in the material used to dissolve alumina.
D F^- present in water used to quench the molten metal.

Z16 Uranium extraction

Z16-1
80
D

Uranium ore is often concentrated close to the mine site and shipped in a form called 'yellow cake'. The approximate composition of yellow cake is

A UO_2. B UO_3. C U_2O_3. D U_3O_8.

Z16-2
40
A

The final stage in the isolation of uranium metal from uranium ore usually involves reduction of UF_4 with

A magnesium. C carbon monoxide. E manganese(IV) oxide.
B carbon. D hydrogen.

Z16-3
20
C

Which of the following procedures is part of the usual process used to extract uranium metal?

A extraction of impurities in a slag
B selective flotation of ore using sodium ethyl xanthate
C roasting followed by leaching with sulfuric acid
D high temperature reduction of yellow cake with carbon monoxide
E electrolytic precipitation of metal ions in ammonia solution

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